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Cover: Short-horned Lizard, *Phrynosoma hernandesi*, adult female, July 1996, Rock Creek Coulee, East Block, Grasslands National Park, Saskatchewan. Photo courtesy G. L. Powell. See Status Report on short-horned lizards by Powell and A. P. Russell pages 1-16.

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OTTAWA

CANADA

The Status of Short-horned Lizards, *Phrynosoma douglasi* and *P. hernandezi*, in Canada*

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Powell, G. Lawrence, and Anthony P. Russell. 1998. The status of short-horned lizards, *Phrynosoma douglasi* and *P. hernandezi*, in Canada. *Canadian Field-Naturalist* 112(1): 1–16.

Short-horned Lizards reach their northern distribution limits in British Columbia, Alberta, and Saskatchewan. Two specimens of the Pygmy Short-horned Lizard (*P. douglasi*) were reported in 1898 from the vicinity of Osoyoos, British Columbia; there have been no validated sightings since. It was probably found on the sandy lacustrine terraces lining the bottom of the Okanagan Valley in the vicinity of Osoyoos Lake, but intensive searches of this area in August 1991 were negative. The Short-horned Lizard (*P. hernandezi*) has an interrupted distribution in southeastern Alberta and southwestern Saskatchewan. The vegetation within its range in these provinces is mixed grass prairie within the dry steppe climatic region. Populations in these provinces are confined to south-facing slopes, grassland-badlands ecotones, and Bearpaw shale outcrops. The distribution appears to be relictual. *Phrynosoma douglasi* is apparently extirpated in British Columbia and *Phrynosoma hernandezi* is vulnerable in Alberta and Saskatchewan.

Key Words: Pygmy Short-horned Lizard, *Phrynosoma douglasi*, Short-horned Lizard, *Phrynosoma hernandezi*, distribution, status, extirpated, vulnerable, British Columbia, Alberta, Saskatchewan.

The genus *Phrynosoma* contains 14 species of distinctive, relatively small, depressed, spiny lizards (Sherbrooke 1981; Zamudio et al. 1997) now placed in the family Phrynosomatidae (9 genera, 100+ species; Zug 1993) by some authors (Estes and Pregill 1988; Frost and Etheridge 1989), but is retained as a subfamily (Phrynosomatinae) of the composite family Iguanidae by others (Zug 1993). *Phrynosoma* occurs throughout western North America (from British Columbia east to Saskatchewan and western Arkansas) and south to Guatemala (Stebbins 1985). They are unlikely to be confused with any other group; the nearest lizard in appearance is the unrelated spiny ecological equivalent in the deserts of Australia, the Thorny Devil, *Moloch horridus* (see Zug 1993).

The Short-horned Lizards, long recognized under the name *Phrynosoma douglassi* (Figure 1), have the most extensive range within the genus *Phrynosoma* and are distributed over much of western North America (Smith 1946; Reeve 1952; Sherbrooke

1981) (Figure 2). Six subspecies have traditionally been recognized, and collectively these range from west-central Mexico in the south to southern British Columbia, Alberta and Saskatchewan in the north (Reeve 1952; Logier and Toner 1961). Their ranges in the United States and Mexico are described by Reeve (1952); Stebbins (1985) omitted recognition of subspecies. Habits, reproduction, and diet for various areas over the range are described by Smith (1946), Milne and Milne (1950), Pianka and Parker (1975), Guyer (1978), Guyer and Linder (1985), Montanucci (1981), Sherbrooke (1981), Powell and Russell (1984, 1985a, 1985b, 1991a, 1991b, 1992) and Russell and Bauer (1993).

The traditional spelling of the specific name (*douglassii*) was recently corrected to *douglasi* by Hammerson and Smith (1991). We follow that usage here although Smith (personal communication to F. R. Cook) has pointed out that the choice of the single "i" ending is not validly in effect until the new edition of the International Code of Zoological Nomenclature is published.

The monophyletic nature and subspecific classification of the Short-horned Lizards have recently been examined by Zamudio et al. (1997), whose phylogeographic tree, based upon mitochondrial DNA haplotypes, depicts a paraphyletic *P. douglasi*. Populations previously assigned to *P. d. douglasi*,

*Status assigned by COSEWIC April 1992 as: *P. d. douglassii* British Columbia — Extirpated; *P. d. brevirostre* Alberta and Saskatchewan — Vulnerable. Data in this paper have been updated by the authors from the original status report, and the nomenclature revised.

distributed through the Pacific Northwest of the USA, are retained within *P. douglasi*, which is basal to *P. ditmarsii* (Zamudio et al. 1997). The remaining subspecies, previously assigned to *P. douglasi* and now forming a polytomy with *P. ditmarsii*, are assigned to *P. hernandezi* by Zamudio et al. (1977). There are no subspecific designations for *P. hernandezi*, but two clades based upon haplotypes are evident, one ranging through the Great Basin and Colorado Plateau and the other found principally upon the northwestern Great Plains (Zamudio et al. 1977). Most of the specimens previously designated as *P. d. brevirostre* examined by Zamudio et al. (1977), including three from Alberta, were assigned to this latter clade, forming (with the exception of one population in southern Colorado, near the southern limit of *P. d. brevirostre*'s distribution) a monophyletic grouping within Zamudio et al.'s (1977) phylogeny for the *P. douglasi* complex.

Here we follow Zamudio et al.'s (1977) classification for the populations of the former *P. douglasii* found in Canada, assigning the British Columbia populations to *P. douglasi* and the Alberta and Saskatchewan populations to *P. hernandezi*. No vernacular names have yet been assigned to these species, and so we will continue to refer to *P. douglasi* as the Pygmy Short-horned Lizard and will refer to *P. hernandezi* as the Short-horned Lizard. References here to *P. douglasi* (*sensu lato*) or to the Short-horned Lizard (*sensu lato*) denote general reviews of the literature from before Zamudio et al.'s (1977) reassessment of *P. douglasi* and *P. hernandezi*.

Distribution

Two species of *Phrynosoma* have been recorded in Canada (Figure 3); the Pygmy Short-horned Lizard (*P. douglasi*) in southern British Columbia, and the Short-horned Lizard (*P. hernanderi*) in southeastern Alberta and southwestern Saskatchewan (Smith 1946; Schmidt 1953; Logier and Toner 1961; Cook 1984). Although Reeve (1952) did not list any Canadian localities for either of these, he did note one specimen of the Short-horned Lizard taken on the Milk River at 49°N, and extended its range marginally into Alberta on his map. Conant (1975), Stebbins (1966, 1985) and Behler and King (1979) noted that the range of Pygmy Short-horned Lizards extends north into southern British Columbia in the west, and that of Short-horned Lizards into southern Alberta and Saskatchewan in the east, although the various limits given by these authors are not totally congruent.

British Columbia

Fannin (1898) recorded the Pygmy Short-horned Lizard from Osoyoos, in the Okanagan Valley just north of the Washington border, based on two specimens in the British Columbia Provincial Museum

(now the Royal British Columbia Museum). Cowan (1936), apparently citing the same specimens, stated they were collected in 1910. Logier and Toner (1955, 1961), Carl (1968), Gregory and Campbell (1984) and Stebbins (1985) reiterated this date, but Orchard (1980) corrected it and Cook (1984) cited it as "late in the last century". The specimens are thought to have been collected on the east side of Osoyoos Lake, in the area presently within Osoyoos Indian Reserve 1 (Anonymous 1990*), although this is apparently unsubstantiated (S. Orchard, personal communication, 8 October 1991). Schmidt (1953) listed the Pygmy Short-horned Lizard as being found in south-central British Columbia. Carl (1968) raised the possibility that it is found in the Keremeos region, apparently on the basis of an ambiguous mention by Anderson (1901), which, however, referred to the Okanagan region as a whole. Orchard (1980) noted that subsequent sightings have been reported in the Osoyoos region, but felt that few had any credibility (S. Orchard, personal communication, 22 October 1991). A 1937 report, from the general region of Osoyoos, is apparently valid (S. Orchard, personal communication, 4 April 1997), corroborating Fannin's (1898) original report. Infrequent but persistent anecdotal reports of Pygmy Short-horned Lizards from the area immediately to the north of Osoyoos over the past two decades (Orville Dyer, personal communication, 27 May, 1997), give faint promise that a population may still be found in the area.

A ten-day search by one of us (Powell) in August 1991 covered all the suitable undisturbed habitat to the east of Osoyoos Lake, under apparently ideal weather conditions for sighting this species, but no horned lizards were seen. None of the local people interviewed recalled ever having seen one or hearing of one being seen. It is likely that this population was a peripheral isolate and that it is now extirpated from British Columbia. The closest recorded population to the south is at the south end of Okanagan County, Washington (Nussbaum et al. 1983), some 100 km to the south of Osoyoos.

Alberta

Logier and Toner (1961) stated that the Short-horned Lizard in Alberta ranges through "... south-western [sic] Alberta northward to about 50° latitude", and record specimens from Manyberries, Onefour, and Medicine Hat. Williams (1946) recorded specimens from Chin Coulee at Foremost, Bear Gulch east of Aden, the Lost River canyon, Manyberries, and the lower Milk River Canyon. Soper (1949) recorded the lizard from Chin Coulee north of Nemiskam, and stated that it was found in

*See Document Cited section after Acknowledgments but preceding Literature Cited.

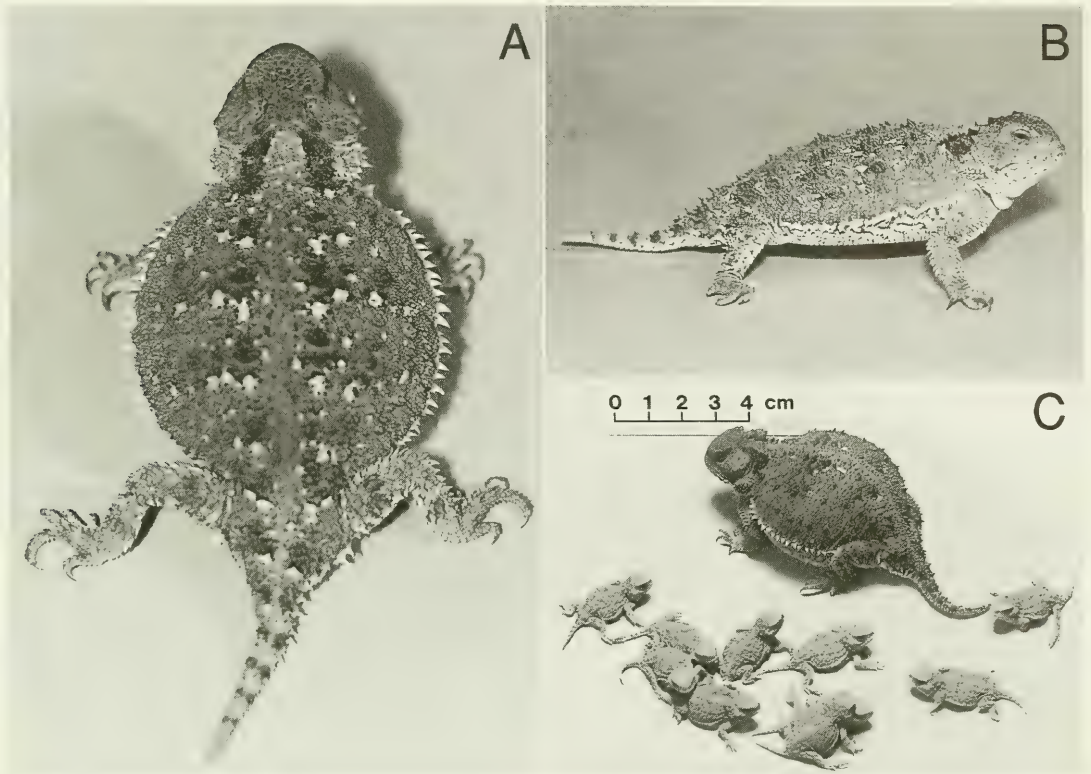


FIGURE 1. *Phrynosoma hernandesi*. A. Dorsal view, adult female (Comrey, Alberta). B. Lateral view, adult female (Comrey, Alberta). C. Female with litter of ten neonates (Bow Island, Alberta).



FIGURE 2. Distribution of the Short-horned Lizards in North America after Stebbins (1985). The Pygmy Short-horned Lizard occupies the northwestern portion of this range.

widely-scattered coulees and along the Milk River valley and associated tributary drainage areas. Lewin (1963) recorded it from Foremost, Comrey, Manyberries, the vicinity of Onefour, and the vicinity of Wildhorse. Schowalter (1979) listed three range-marginal localities for this province: on the east bank of the South Saskatchewan River 16 km northeast of Medicine Hat; on the north bank of the South Saskatchewan River 9 km northwest of the town of Bow Island; and on the south bank of the Milk River just east of Writing-on-Stone Provincial Park. Milner (1979) recorded the species along the Milk River canyon and along southeastern parts of the Red Deer River, but this last locality was disputed by Laird and Leech (1980), who noted that there were no other records of this lizard so far north. Laird and Leech (1980) recorded it from the north bank of the South Saskatchewan River, 20 km south of Suffield, and from the north side of the Milk River 8 km south of Onefour.

Additional localities in Alberta are documented from museum specimens. The collection of the University of Alberta Museum of Zoology contains two specimens from the vicinity of Redcliff (UAMZ 129, 130). The Herpetology Collection of the

Canadian Museum of Nature (formerly the National Museum of Canada, National Museum of Natural Sciences) contains one specimen from the north bank of the South Saskatchewan River 11 km west of Redcliff [NMC 3479 (1)], one from the Lost River Ranch 9 km northwest of Onefour [NMC 7333(2)], one from Grassy Lake [NMC 1020(1)], and one from Writing-on-Stone Provincial Park [NMC 1829(1)]. A specimen from Nemiskam County Pasture, 19 km southeast of Manyberries, is deposited in the Zoology Collection of the University of Calgary [UCMZ(R) 1980.19]. Locality data on some of these specimens must refer to the closest identifiable landmark rather than the actual capture site; the Grassy Lake locality must either refer to the stretch of 40-Mile Coulee to the south of the town of Grassy Lake, or to the confluence of the Bow and Oldman rivers to the north. As the specimen was collected in 1923, this is unlikely to be resolved now.

Anecdotal data (i.e., those not accompanied by a voucher specimens and not reported in the literature by professional observers) are generally trustworthy, as phrynosomes are distinctive and unlikely to be mistaken for some other species of organism found in Alberta or Saskatchewan. We have found that the species is generally known to local people whose daily rounds would take them into its habitat (i.e., ranchers, range riders, and oil field workers) when it occurs in their working areas. The only two localities vouched for anecdotally in Alberta are the 40-Mile Coulee site and the Second Laidlaw site (Figure 4). Repeated searches of the 40-Mile Coulee site for phrynosomes in the summer of 1991 were fruitless. The population may be extinct. We examined the Second Laidlaw site desultorily in the same field season and found no lizards.

The range of the Short-horned Lizard extends north to 50°10' in Alberta (Figure 4). The distribution appears to be fragmented. One group of populations is found along the South Saskatchewan River. Another group is distributed through the Milk River and Pakowki Lake drainages, but seems to be broken into eastern and western subgroups, with no populations found between those in the western Milk River valley and those in the east. The Chin Coulee and 40-Mile Coulee populations lie isolated between the northern and southern groups. The South Saskatchewan River forms the northern boundary of the recorded range in this province. There are no records east of Wildhorse in Alberta, and the Cypress Hills mark the eastern border of the range to the north. Similarly, to the southwest the Sweetgrass Hills seem to confine populations to the Milk River valley. The maximum elevation at which any population is found is around 1100 m, along the southern edge of the Cypress Hills and on the south side of the Milk River canyon. Most of the rest of

the southern populations are found at 900 m. The Chin Coulee populations are found at 800 m, as is the one in 40-Mile Coulee, while those lying along the South Saskatchewan River reside at 700 m. The absence of the population in suitable habitat at Red Rock Coulee (elevation 980 m; 49°32'N) suggests that there is a rapid decrease in elevation attained with increasing latitude, even over the latitudinal range in Alberta; phrynosomes are found in similar habitat at this elevation 35 km to the south.

Saskatchewan

There are relatively few records of the Short-horned Lizard in Saskatchewan (Secoy 1976). Its range in this province seems to be disjunct from that in Alberta (Figure 3). It is recorded from Gergovia (Logier and Toner 1961; Cook 1966; Secoy 1976) and Rosefield (Nero 1957; Logier and Toner 1961; Cook 1966; Secoy 1976), in the Frenchman River valley. Chandler (1965) notes a single specimen from eleven km south of Val Marie, again in the Frenchman River valley. Secoy (1976) recorded it from Killdeer and Val Marie as well, and stated that distribution is limited to the Frenchman River valley. However, the Killdeer locality lies in the Poplar River drainage system, which, like the Frenchman River, is a tributary of the Missouri. The Killdeer locality actually refers to a Canadian Museum of Nature specimen (NMC 15499), collected in the Butte Creek drainage, within the proposed boundaries of the East Block of Grasslands National Park (Powell and Russell 1996c*). NMC records list additional sightings from Seventy-Mile Butte, from Coal Creek, southeast of Killdeer, and from Whitemud Creek [now the Frenchman River] where it crosses the U.S. border, but specimens were not collected. Secoy (1976) suggests that the Short-horned Lizard may occur in the area of the Big Muddy Creek. Nero's (1957) correspondent reported it to be found anywhere in the Rosefield area where there are shale outcrops. Powell and Russell (1996c*, 1996d*) found that it was relatively common in the Bearpaw formation badlands of the Frenchman River valley southeast of Val Marie, and relatively uncommon in the Rock Creek drainage immediately north of the U.S. border in the proposed East Block of Grasslands National Park.

The range of the species in Saskatchewan appears to be restricted to the northwest by the Cypress Hills, to the northeast and east by Pinto Butte and Wood Mountain, and to the west by the Boundary Hills. The distribution thus extends no further north than 49°15'N. The populations in the Frenchman River valley lie at approximately 770 m - 860 m elevation, while those in the Wood Mountain area are found at an elevation of roughly 860 m. The Frenchman River valley populations appear to be restricted to the valley itself and its immediate tributary coulees, while those in the East Block of Grasslands National



FIGURE 3. The distribution of the Pygmy Short-horned Lizard, *Phrynosoma douglasi* (British Columbia) and the Short-horned Lizard, *P. hernandezi*, (Alberta and Saskatchewan) in Canada.

Park are mainly found on the coulee slopes (Powell and Russell 1996c*, 1996d*).

Protection

British Columbia

Orchard (1980) recommended that the Pygmy Short-horned Lizard in British Columbia should be accorded immediate protection, along with its habitat, should any be found. It is classified as wildlife under the British Columbia Wildlife Act of May 1990, protected but having no special status except for management purposes (C. Dodd, personal communication 31 October 1991). At present it is also on the Red List (potentially threatened/endangered) of the British Columbia Ministry of the Environment, Lands and Park's Wildlife Branch.

Alberta

The Eastern Short-horned Lizard has full protection under the Alberta Wildlife Act of March 1991 and accompanying regulations. It was formerly Red Listed in Alberta (populations are nonviable or at immediate risk of declining to nonviable levels - Anonymous 1991*), but has been recently reas-

signed to the provincial Blue List (may be at risk due to noncyclical population declines, or reductions in habitat or provincial distribution - Anonymous 1996*). As such, it may be considered for designation as Endangered Species in Alberta (Anonymous 1996*), pending the evaluation of a more detailed provincial status report (James et al. 1997*). It has been the subject of field research, pertinent to the framing of management policy, promoted by Alberta Environmental Protection's Fish and Wildlife Services in the past decade (Powell and Russell 1996a). Very few of the populations in Alberta lie within protected habitat. The Milk River Natural Area encompasses the Comrey population, and any populations which may lie on the south side of the Milk River (Anonymous 1984*). Exploration and development of a site where horned lizards are known to occur now requires impact assessment and impact mitigation.

Saskatchewan

All reptiles and amphibians are protected under the provincial Wildlife Act in Saskatchewan, but the Eastern Short-horned Lizard has no official status in that province. Unofficially, any anthro-

List for numbered localities for Figure 4 (see facing page)

1 – Manyberries (Logier and Toner 1955, 1961; Lewin 1963; NMC 1922, 3482; UAMZ 40, 97, 122-126); 2 – Onefour (Logier and Toner 1961; UAMZ 41, 42, 277, 278, 280, 281) – Medicine Hat (Logier and Toner 1961; NMC 356, UAMZ 13, 131; D. Berisco, personal communication); 4 – Chin Coulee at Foremost (Williams 1946; Lewin 1963; NMC 1147, 1830; Powell and Russell 1992); 5 – Bear Gulch (Williams 1946); 6 – Nemiskam National Park (Soper 1949; Powell and Russell 1992*); 7 – Comrey (Lewin 1963; Powell and Russell 1984; NMC 1857, UAMZ 128; UCMZ(R) 1980.20, 1980.21, 1980.25; Powell and Russell 1992); 8 – Wildhorse (Lewin 1963; UAMZ 276); 9 – 16 km NE of Medicine Hat (Showalter 1976); 10 – 9 km NW of the town of Bow Island (Showalter 1979; Powell and Russell 1984; UCMZ(R) 1980.22, 1980.23, Powell and Russell 1992*); 11 – Audet Ranch (Schowalter 1979, NMC 1829); 12 – Rose Ranch, 20 km S of Suffield (Laird and Leech 1980; Powell and Russell 1984; UAMZ 156, 157); 13 – North bank of Milk River, 8 km S of Onefour (Laird and Leech 1980; UAMZ 93, 98-102); 14 – Redcliff (UAMZ 129, 130); 15 – North

Bank of South Saskatchewan River, 11 km W of Redcliff (NMC 3479); 16 – Lost River Canyon, 9 km S of Onefour (NMC 7333); 17 – Grassy Lake (NMC 1020); 18 – 20 km SE of Manyberries (L. Strong, personal communication; Powell and Russell 1992*); 19 – Lost River Canyon W of Onefour (L. Strong, personal communication, NMC 1284); 20–20 km SE of Manyberries (L. Harder, personal communication; Powell and Russell 1992*); 21 – Nemiskam Community Pasture (Powell and Russell 1984, UCMZ(R) 1880.19; R. Lee, personal communication, Powell and Russell 1992*); 22 – McKinley's Ranch (Powell and Russell 1984; Powell and Russell 1992*); 23 – North edge of Milk River Canyon (Lewin 1963; Smith 1975; UAMZ 279); 24 – Lost River Canyon (Lewin 1962; UAMZ 43, 94); 25 – 40-Mile Coulee (M. Nelson, personal communication); 26 – Second Laidlaw (L. Milne, personal communication); 27 – McDonald Coulee (Powell and Russell 1992*); 28 – Lecuyer's Coulee (W. Smith, personal communication; Powell and Russell 1992*); 29 – Chin Coulee, 3 km E of Foremost (Powell and Russell 1991^a, 1992*).

pogenic disturbance is discouraged for 100 m around habitat used for breeding by phrynosomes (Wayne Harris, personal communication, January 1997; Earl Wiltse, personal communication, January 1997). Preparations are currently underway to emend the provincial Wildlife Act, allowing designation of "at risk" to any native species found within the province judged to merit it. Species will be listed by regulation and categorized according to perceived status in the province (the categories to be used are not yet in place - Earl Wiltse, personal communication, January 1997). Short-horned Lizards will presumably be assigned to the "at risk" designation.

The area of the proposed Grasslands National Park will be fully protected by the National Parks Act when the Park is incorporated. The process, however, may take some time. At present, the areas within the proposed West Block boundaries which are Park property contain a great deal of suitable habitat, and most of the recorded Saskatchewan Short-horned Lizard localities (Powell and Russell 1996c*, 1996d*) are effectively protected by local Park policy even though the Park has not been formally incorporated (Pat Fargey, personal communication, 9 August 1995). The East Block records lie within the proposed Park boundaries, but not on land presently within the Park (Powell and Russell 1996c*, 1996d*).

Population Size and Trends

Alberta is the only province for which we have any data regarding Short-horned Lizard population sizes. The species was probably never common in British Columbia (Orchard 1980). Secoy (1976) states that localities in Saskatchewan are represented

by single specimens, although Nero's (1957) correspondent implied that lizards were relatively common in the Rosefield area. Field work in the West Block of Grasslands National Park in August of 1995 indicated that Short-horned Lizards were not as common there as in comparable habitat in Alberta (Powell and Russell 1996c*, 1996d*), although they were not so rare as to cause concern. They were considerably less common in the lower Rock Creek coulee, in the East Block of Grasslands National Park, but their distribution appears to be very patchy there (Powell and Russell 1996c*, 1996d*).

Some data on population sizes of the Short-horned Lizard in Alberta were gathered by Powell (1982), in a study of the ecology of the subspecies in this province. Five populations were examined in this study (Comrey, Nemiskam Community Pastures, McKinley's Ranch, Rose Ranch, and Bow Island) in 1979, 1980, and 1981. 316 individuals were captured, marked and released at these localities in the course of the study (Comrey - 87; Nemiskam Community Pastures - 78; McKinley's Ranch - 18; Rose Ranch - 8; Bow Island - 125). These figures represent the total number of individuals captured at each of these sites, and no effort was made to estimate population size, due to irregular sampling intervals and low population densities (Powell 1982). Long-term recapture success at these localities was roughly 29% (Powell and Russell 1985a), implying that adult survivorship was high over the period of the study. Horned lizard population densities are generally relatively low (Pianka and Parker 1975), and this was found to be the case in Alberta. The lizard, however, was by no means rare in the localities where it is found - two to three individuals were captured a day, on the average, at



FIGURE 4. The distribution of *Phrynosoma hernandesi* in southeastern Alberta (hatched area of inset map), in relation to elevation and drainage. Elevation in meters. References following each locality document literature references, specimen number (NMC: Canadian Museum of Nature; UAMZ: University of Alberta Museum of Zoology; UCMZ(R): University of Calgary Museum of Zoology), or anecdotal report (personal communication). For a list of numbered localities, see facing page.

the localities examined by Powell (1982). Local residents in the area of the range in Alberta are generally familiar with the species. The populations examined by Powell (1982) seem to be strongly localized and isolated, although this is, of course, difficult to determine with any assurance.

In the summer of 1991, an attempt was made by us to verify the localities reported in the literature for Alberta, and to evaluate present population sizes (Powell and Russell 1992*). Only half of the Alberta localities presented in Figure 3 were visited (as indicated in the caption). Capture success was

much lower in the summer of 1991 than in the summers of 1979, 1980, 1981, or 1983. Although individuals were captured at most sites examined, they were not as abundant as in the early 1980s. Even site such as Comrey and Bow Island, where horned lizards had previously been found to be relatively abundant, yielded low numbers in 1991. The spring and early summer of 1991 were unusually cold and rainy, which would discourage activity and make lizards more difficult to find, and only a small amount of time could be spent at each locality. Nevertheless, even accounting for these factors, the overall abundance seems to have decreased. The only sites where lizards were found to be abundant in 1991 were those associated with the juniper dune areas to the north and south of the Manyberries Creek - Sage Creek valleys, southeast of Manyberries. This impression of general reduction over the Alberta range could be due to prolonged drought conditions in this area over much of the preceding decade. Relatively few fully adult individuals (as defined by the growth models of Powell and Russell 1985b) were encountered, suggesting a change in the overall demographic profile (Powell and Russell 1993a). Anecdotal reports from long-time residents of southeastern Alberta also indicate a decrease in horned lizard abundance. While there is bound to be a certain amount of subjectivity in these, it is interesting that they parallel our own field data.

The 40-Mile Coulee population appears to have disappeared. Although the source of anecdotal past reports, the most recent of these was in the early 1980s, and we found none there in 1991. A single adult was captured in a subdivision north of Police Point in Medicine Hat in the summer of 1988 (D. Berisco, personal communication, June 1991). Repeated searches of the area have yielded no additional specimens since, although there are anecdotal reports of encounters at the Medicine Hat Golf and Country Club. This population may also have been extirpated.

Habitat

Phrynosoma douglasi (*sensu lato*) is a non-desert species of phrynosome (Heath 1965), found in a variety of habitats over its latitudinal range. In northern Mexico it is confined to high-elevation open grassland (Montanucci 1981); in Arizona, New Mexico, Utah, and Nevada it inhabits sagebrush steppe, pine forest, and juniper-piñon woodlands (Smith 1946; Reeve 1952; Montanucci 1981), while in the north of its range it is found in sagebrush communities and semi-arid short-grass prairie (Smith 1946; Sherbrooke 1981; Powell and Russell 1984). The Short-horned Lizard is always found at high elevations, but its upper altitudinal limit is closer to sea level in the northern part of its range (Montanucci 1981).

British Columbia

Cowan (1936) described the area in which the Pygmy Short-horned Lizard is found in British Columbia as "Upper Sonoran Zone", but nothing else is available on the specific habitat favoured by the species in this province. The only specimen record is from Osoyoos in the Okanagan Valley. The elevation of the valley bottom ranges between 280 m and 380 m, while surrounding mountains range from 2100 m to 1800 m. The soil of the area is classified as A2₅₂ in the soils of Canada inventory (Clayton et al. 1977). The climate is warm and dry; the mean daily temperature is greater than 22° C in July, and the average frost-free period is 100–140 days, while precipitation is less than 30 cm per year (Farley 1979). Osoyoos lies within the Ponderosa Pine - Bunchgrass biogeoclimatic zone (Farley 1979). The valley bottom on the eastern side of Osoyoos Lake consists largely of flat, xeric, sandy lacustrine terraces, differing mainly in their elevations above the lake. The vegetation communities of this area are dominated by *Stipa* and by stands of Antelope Brush and sage. The lower slopes of the valley wall on the east side have similar vegetation, with the addition of Ponderosa Pine stands, are somewhat less xeric, and are generally oriented towards the southwest.

Alberta

The Short-horned Lizard is found within the dry steppe climatic region of Alberta (Longley 1977). The growing season begins around 15 April, and the mean date of the last spring frost is between 15 May and 1 June (Longley 1977). Summers are hot, the mean July temperature over the range varying between 19°C and 20° (Longley 1977). There is a mean of 1300 hours of sunlight between May and September over most of the range, increasing to 1400 hours in the area around Bow Island and Grassy Lake (McKay 1965). This region receives the most sunlight in July (Coupland 1950). The average date of the first fall frost is later than 15 September over the range, for an average frost-free period of 120 days (Longley 1977). Total annual precipitation over the range averages 33 cm, most of which falls between April and October, with a peak in July. The climate in the summer over the range can best be described as hot and dry.

The vegetation of the range in Alberta has been described by Coupland (1950, 1961) and North (1976). Wallis (1976) has described in some detail the vegetation of the eastern part of the Milk River Valley. The climax vegetation in this area is the mixed grass prairie association. Its dominant faciation is the *Stipa* - *Bouteloua* (Coupland 1950). In the drier area south of the Cypress Hills this is replaced by the *Bouteloua* - *Stipa* faciation (Coupland 1950).

In the Milk River Valley, and the associated Lost River canyon and Onefour regions (Figure 3: localities 2, 5, 8, 11, 13, 16, 19, 23, 27) populations are

generally found on ecotones, particularly coulee and canyon rims (this tendency seems to be more pronounced in the western populations), but also on breaks, the edges of badland areas which may or may not be associated with coulees or canyons. South-facing slopes are favoured, but not exclusively, and individuals may be found in the grasslands, some distance away from the coulee or canyon edge with which they would normally be associated, or down in the coulee bottoms.

Populations in the high terrain to the north and south of the common valley of Manyberries and Sage creeks (Figure 3: localities 1, 18, 20, 21, 22, 28) are almost invariably associated with Bearpaw shale exposures. This formation is surficial at the south and west extremities of the Cypress Hills. It is friable and tends to form extensive badlands of 2 m dunes, interspersed with alluvial flats, in wide, shallow coulees and ravines cut into the north and south sides of the valley, and into the south side of the isolated ridge forming the south side of the valley. Creeping Juniper (*Juniperus horizontalis*) is the dominant plant on this substrate, forming large mats which serve to anchor the dunes, but the total vegetation cover in these juniper dune areas is not greater than 50%. The higher areas between juniper dune terrain are flat or gently sloping, and generally support a typical short-grass prairie vegetation. Towards the western end of Manyberries Creek Valley the juniper dune terrain becomes more precipitous, descending steeply from outliers of the Cypress Hills. Phrynosomes are found throughout this terrain, occupying the juniper dune areas, the edges of the associated coulees and ravines, and the grassy areas between these. Lizards have been found in juniper dune terrain down as far as the valley bottoms, but not on the alluvial flats of the valley bottom itself. Densities are not great but distribution appears to be continuous along the north side of the Manyberries and Sage creek's common valley. Short-horned Lizards are in fact the most commonly encountered reptile species in this area. They have been found at elevations of 1035 m above sea level at the west end of this valley (Smith 1993*). Similar terrain further north is not occupied, perhaps because its elevation is too great at that latitude. This habitat is probably the most important to the species in Alberta, due to its great continuous extent and the ubiquity of horned lizards throughout it.

The populations found along Chin Coulee and the South Saskatchewan River (Figure 3: localities 3, 4, 6, 9, 10, 12, 14, 15, 17, 25, 26, 29) appear to be restricted to the upper slopes of the canyon or coulee. Generally populations are found in areas where the channel rim is dissected into a series of draws and spurs, forming suites of slopes of varying aspect and grade. The horned lizard populations are found on the upper, vegetated third or so of these

slopes, seldom descending any distance down the bare lower slopes and never venturing onto the flat grasslands at the top. Populations may also be found on the less complex upper slopes of more extensive tributary coulees coming off the main channel. Populations along the South Saskatchewan River were invariably on the north bank, occupying predominately south facing slope complexes, with the exception of the northernmost population reported by Schowalter (1979), which is on a series of west-facing spurs on the east side of the river. Populations in Chin Coulee may be found on the north or south side of the coulee, but otherwise inhabit similar situations to those along the South Saskatchewan River.

Saskatchewan

There is little published information on the habitat of the Short-horned Lizard in Saskatchewan. Nero's (1957) correspondent reported it as being found in the badlands where there are outcrops of "blue shale". Secoy (1976) indicated that it is found in the badlands, and Chandler (1965) also recorded it from badlands near Val Marie. The Frenchman River valley southeast of Val Marie is wide and flat-bottomed, with deeply-dissected sides. The area is underlain mainly by the Bearpaw formation (Richards and Fung 1969), which forms extensive badlands along the sides of the valley and occupies most of the side-coulees. All of the phrynosomes found in our 1995 field work in the Frenchman River valley were in these Bearpaw badlands, which are very similar to those of the Manyberries area of Alberta (Powell and Russell 1996c*, 1996d*). In the East Block of Grasslands National Park, the terrain is typical rolling mixed-grass prairie, cut by deep coulees through Ravenscrag Clay; all captures were made along the slope of Rock Creek coulee, on patches of relatively thinly-vegetated soil in an otherwise well-vegetated area (Powell and Russell 1996c*, 1996d*). Short-horned Lizards were not found very far north of the U.S. border in this area; the terrain rises rapidly to 950 m at the north end of the Block, on the lower slopes of Wood Mountain (Powell and Russell 1996c*, 1996d*). The soil of this area of Saskatchewan is classified as Al_{18} over most of the range, with some occurrence of B_{15} . These soils have similar characteristics to their counterparts in Alberta (Clayton et al. 1977). The climate is classified as dry steppe (Longley 1977), with short hot summers and 30–35 cm of precipitation annually (Richards and Fung 1969). The average frost-free period ranges in length from 60 to 80 days, beginning from 1 June to 10 June, and ending between 1 September and 10 September (Richards and Fung 1969). The vegetation is mainly the *Bouteloua - Stipa* faciation (Coupland 1950), in other regards being similar to the range in Alberta.

General Biology

Habits, reproduction and diet of the Short-Horned Lizard (*sensu lato*) for various areas over the entire range are described by Smith (1946), Pianka and Parker (1975), Guyer (1978), Montanucci (1981), Sherbrooke (1981), and Powell and Russell (1984, 1991b, 1993).

The Short-horned Lizard (*sensu lato*) is viviparous (Smith 1946; Pianka and Parker 1975; Sherbrooke 1981), a moderately uncommon reproductive mode among reptiles and one that may permit it to persist in colder climates. Few data on clutch size are available for this species elsewhere in its range. Smith (1946) states that clutch sizes range from 5 to 30 neonates. Milne and Milne (1950) recorded clutch sizes ranging from 7 to 21 neonates, and gave some details on parturition. These authors indicated that the gestation period is approximately three months long, mating taking place in early May and parturition occurring in late July to mid-August. Goldberg (1971) examined the testicular and gonadal cycles of short-horned lizards in Arizona.

No data on reproduction in the British Columbia populations of the Pygmy Short-horned Lizard and Saskatchewan populations of the Short-horned Lizard are available, but some observations on clutch size and parturition in Alberta Short-horned Lizards have been made. Laird and Leech (1980) observed parturition in a specimen from a South Saskatchewan River population, in which seven young were born. One specimen (UAMZ 131) taken in Medicine Hat gave birth to 13 young. Powell and Russell (1991b) examined six clutches delivered by females from Bow Island and Comrey. Clutch size ranged from six to eleven young. Neonates averaged about 24 mm in snout-vent length (SVL), and weighed an average of 0.7 g. Sex ratios varied between clutches, but overall approximated 50:50, with a slight bias in favour of females. Parturition occurs from the last week of July to the first week of August, and seems to be synchronized - no gravid females were found in any of the Alberta populations examined after the first week of August except in 1993, in which a cold wet summer was preceded by a late spring and in which no neonates had been seen by 10 August although young-of-the-year were abundant at the same locality in early September. There are indications that parturition takes place around noon. Survivorship of the young has not been assessed at present. Gravidity evidently imposes a considerable physiological strain on reproducing females, and this was thought to act as a range limiting factor, since they must recover lost weight in a limited period before the onset of hibernation (Powell and Russell 1991b). However, radiotelemetric studies of individual females at a Manyberries Creek valley population indicated that weight was recovered during the month after parturition, followed by a slight weight loss through

September and October, which speaks against this theory (Powell and Russell 1994*, 1996b*).

Powell and Russell (1985b) examined growth and sexual size dimorphism in the Alberta populations of the Short-horned Lizard. Sexual maturity is attained, in males, in the summer after the first winter dormancy; the onset of sexual maturity in females could not be determined. Males attain an average adult snout-vent length (SVL) of approximately 50 mm and a maximum adult weight of 10 g. Females continue growing to an average adult SVL of approximately 70 mm and an adult non-gravid weight of approximately 18 g. This disparity in adult size between the sexes is probably related to the species' viviparity (Powell and Russell 1985b). Recapture records suggest that females live as long as five years, but no such estimate could be made of male lifespan (Powell and Russell 1985b).

The earliest published record of activity for the Short-horned Lizard in Alberta is 27 April (Laird and Leech 1980), and apparent activity has ceased by mid-September (personal observation); these dates bracket activity in the summer habitat, although males have been encountered on the surface as early as 1 April (Powell and Russell 1994*) and female activity has been recorded on the surface (through radiotelemetry) as late as 10 November (Powell and Russell 1996b*) in the autumn habitat (see below). The active season may thus be approximately 220 days long, beginning well before the mean date of the last spring frost and ending well after the mean date of the first fall frost. This, with some anecdotal evidence, suggests some ability to resist freezing or at least to avoid freezing conditions (Powell and Russell 1993b*, 1994*, 1996b*), although this has not been investigated in the laboratory. These populations exhibit considerable eurythermality (Powell and Russell 1985a) and this is also important in extending daily activity periods on the margins of the active season and in permitting activity on cool, overcast days. Most lizards have apparently disappeared by the mean date of the first fall frost, but this appears to be due to a shift in the area of activity; lizards at the Alberta locality of our radiotelemetry studies shifted activity into more sheltered parts of the habitat, lower down the slopes, and became much less conspicuous in their movements (Powell and Russell 1994*, 1996b*). It is possible that the yearly activity pattern is controlled by an endogenous cycle and photoperiod cues; Mayhew (1965) found such a mechanism in *Phrynosoma mcalli*. A photoperiod cue probably induces the change in behaviour and shift in habitat use in the Alberta populations of the Short-horned Lizard, as there appears to be little change in environmental temperature over the period in which the lizards cease to be active (Powell and Russell 1993b*, 1994*, 1996b*). Further details of the field

thermal ecology of this species in Alberta are to be found in Powell and Russell (1985a); seasonal activity patterns and thermal relations are discussed by Powell and Russell (1993b*, 1994*, 1996b*).

Phrynosomes are specialized as ant eaters (Pianka and Parker 1975) and aspects of their morphology have been related to this diet (Pianka and Parker 1975; Montanucci 1989). The Short-horned Lizard does feature a high proportion of ants in its diet in Alberta, but also preys on a variety of other insects (Powell and Russell 1984). There is some partitioning of the dietary niche between the two sexes; females, due to their greater size, take larger prey items and also a wider size range of prey (Powell and Russell 1984). Short-horned Lizards appear to fast during the month or so before entering hibernation, with some consequent loss of weight (Powell and Russell 1994*, 1996b*).

Movements and habitat use of Short-horned Lizards at an Alberta locality have been examined through radiotelemetry by Powell and Russell (1993b*, 1994*, 1996b*); the findings from these studies and earlier work using mark-recapture techniques are summarized in Powell and Russell (1996b*). Individual movement patterns tend to display long (20+ m) moves at irregular intervals; between these long moves phrynosomes confine activity to relatively restricted temporary ranges. All of Powell and Russell's (1993b*, 1994*, 1996b*) home range area estimates probably represent sections of larger true home ranges defined by seasonal moves of the resident lizards; although this is difficult to test, patterns of movement across the range suggest peripatism within a large, known area, as do our observations of marked individual phrynosomes reappearing in particular areas at similar times in successive years (Powell and Russell 1996b*). The species does not appear to be territorial, but home ranges generally did not overlap in our study area within any given year (Powell and Russell 1993b*, 1994*, 1996b*).

Limiting Factors

The distribution of the Short-horned Lizard (*sensu lato*) in Canada seems to be relictual (Figures 3, 4). The Osoyoos population of *Phrynosoma douglasi* was separated from the closest conspecific population to the south by some 100 km (Nussbaum et al. 1983). The range of *P. hernandezi* is incompletely known in Montana (D. L. Genter, personal communication, 23 September 1991), but it does appear to be continuous with the range in Saskatchewan (Thompson 1982; Reichel and Flath 1995). However, the Montana range (Reichel and Flath 1995) does not appear to match the limits of the Alberta distribution where the two reach the 49th parallel.

There appears to have been a warm, dry xerothermic period from 6000 to 4000 BP on the western

Canadian prairies, during which isotherms were displaced some 150–450 km north of their present positions and the North American prairie was more extensive than it is now (Smith 1965). A number of species which exist as relictual populations in southeastern Alberta (McCorquedale 1965; Wallis 1976; Pendlebury 1976, 1977) probably expanded their ranges into these areas at this time, subsequent climatic cooling causing contraction of these species' ranges into the scattered pockets in which they are found today (McCorquedale 1965). The tributaries of the Missouri River extending into Alberta and Saskatchewan undoubtedly served as the avenues through which these species entered this region. The strong localization and habitat specificity of the Short-horned Lizard, together with the scattered distribution in this area, suggest that it is, in fact, only persisting in scattered localities. Undoubtedly climate is the chief factor affecting the distribution of the species so close to the northern edge of its distribution, but it is difficult to say, on the basis of what is known about its thermal ecology (Powell and Russell 1985b), precisely what climatic factor is limiting. We have hypothesized (Powell and Russell 1991b) that the limits prescribed by a tight reproductive schedule may restrict the species latitudinally in Saskatchewan and Alberta. The timing of reproduction here seems to be much more highly synchronized among individuals than it is further south in the geographic range, and there may be a sharply defined limit, imposed by the annual number of degree-days available, to how far north horned lizards can successfully reproduce (Powell and Russell 1991b). However, more recent work on yearly activity (Powell and Russell 1994*, 1996b*) suggests that climate, as mediated through reproductive biology, does not strongly constrain distribution to its present limits.

South-facing slopes are the usual habitat of the Short-horned Lizard in the prairie provinces. Slopes are excessively drained, due to the lack of thick soil and vegetation (Coupland 1961), and south-facing slopes are more arid than most due to the higher temperatures they experience as a consequence of greater total insolation (Coupland 1961). A south-facing slope has a constant symmetric distribution of temperature and insolation across it during the day, determined by its orientation and grade; south-facing slopes are the warmest at any latitude in the northern hemisphere (Geiger 1965). The strong association of Short-horned Lizard populations with such slopes provides additional evidence that temperature and insolation act strongly to limit the species even within its range in the prairie provinces. Support is given to this hypothesis by the apparent negative association between latitude and elevation of populations in Alberta (Figure 3). In addition, south-facing slopes tend to have thinner

vegetation than those facing in other directions, another horned lizard preference (Reynolds 1979).

The range of the Short-horned Lizard in Alberta is underlain entirely by rocks of the Belly River formation (Williams and Dyer 1930). Pendlebury (1977) hypothesized that the surface occurrence of this formation is a range-limiting factor in the northern distribution of the Prairie Rattlesnake, *Crotalus v. viridis*. He noted that the subsoil produced from Belly River rocks is dry and well drained, and that the rock itself tends to slump and form subsurface cavities which could serve as hibernacula. These features, however, do not appear to be important in determining the northern range limits of the Short-horned Lizard in Alberta. The hibernacula that we have been able to find in southern Alberta were small burrows penetrating, at most, the soil to depths of 7–8 cm (Powell and Russell 1994*, 1996b*), and there are no suggestions that deep subsurface cavities are used by this species in this area.

It is thus difficult to point to any one aspect of the Short-horned Lizard's thermal biology which restricts it to the areas of Alberta and Saskatchewan within which it is found. Possibly there is some synergy of habitat requirements, reproductive biology, and overwinter survivorship which defines the range limits and distribution within them in this area.

Special Significance of the Species

Short-horned Lizards are of no commercial value except possibly to the pet trade, which is unlikely to find them in Canada in sufficient numbers to exploit profitably. The main value of the Canadian populations of this species lies in their scientific interest. There are only five species of lizard in Canada, and these are all at their northern range limits (Logier and Toner 1961; Cook 1964, 1984). The ecology of high latitude lizards is poorly understood (Cloudsley-Thompson 1971; Spellerberg 1976), and studies of the ecology of the Short-horned Lizard in Canada, such as those of Powell and Russell (1984, 1985a, 1985b) have contributed to an increased understanding of this matter. The Canadian populations of this species also have an intrinsic value as unusual components of this country's fauna, which is not particularly rich in reptile species (Cook 1984). Finally, they are noteworthy as the world's most northerly representative of the much studied family Phrynosomatidae (Estes and Pregill 1988; Frost and Etheridge 1989).

Evaluation

Phrynosoma douglasi: BRITISH COLUMBIA:

The Pygmy Short-horned Lizard appears to be extirpated in British Columbia. Reports subsequent to that of Fannin (1898) are too vague to support a belief in the continued existence of a population in this province.

Phrynosoma hernandesi: ALBERTA and SASKATCHEWAN:

The Short-horned Lizard was listed as "threatened" by Roberts (1982) in his assessment of the Alberta herpetofauna and has subsequently been protected by law under the Alberta Wildlife Act of March 1991 in that province. This, together with the nature of human activity over much of its range, makes it doubtful that it is in any danger of disappearing. Large areas of its distribution in Alberta are used only for rangeland, and grazing may actually improve habitat for it (Reynolds 1979), up to a point.

Other land uses can be detrimental to local populations. Irrigation developments have apparently affected at least one Short-horned Lizard population. The large new reservoir occupying 40-Mile Coulee lies under slopes which apparently featured phrynosomes until a decade ago (Powell and Russell 1992, 1993a). Large scale irrigation works such as this, besides possibly damaging the upper reaches of slopes which form the only habitat used by the species in this area, may flood hibernaculum sites and autumn habitat that lie low on the coulee sides. Its advent coincides suspiciously with the disappearance of phrynosomes in this area. Subsequent irrigation works in this area should involve, at the planning stage, an assessment of their possible impact on any phrynosome populations.

Development of coulee and canyon edges, particularly in the South Saskatchewan and Chin Coulee areas, can also have detrimental effects. Cropping as close as possible to the edges of coulees is a practice which appears to have increased with the spread of irrigation. We have found no phrynosomes along coulee edges where a fairly wide border (at least 100 m) is not left undisturbed by the plough. This may also explain the disappearance of the 40-Mile Coulee population. Gas lines, vehicular tracks and roads frequently cross coulee edges, or in some cases run along them. Roads and vehicular tracks are a hazard to such small lizards, particularly as they appear to use the latter to penetrate grassy areas and are thus even more likely to be run over. Gas and oil pipelines unavoidably disturb horned lizard habitat when they are being put in, but we have observed recolonization by lizards in such disturbed habitat after a few years (Powell and Russell 1993a).

Oil and gas exploration may pose the greatest threat to the Short-horned Lizard in Alberta; it appears that a great deal of potential damage has already been done. The juniper dune areas lying along both sides of the Manyberries and Sage Creek valley have been extensively developed for petroleum and gas extraction. Wells, pumping stations, and roads are found throughout the entire region. Mechanical damage to the habitat and hazard

to lizards from traffic are both inevitable consequences. Phrynosomes are still relatively common throughout this region, but there is no way of telling if their numbers have decreased as a result of this development, or of what the continuing cost may be. A great deal of this activity has taken place in the last decade. Areas which require habitat protection are being and have been flagged and reservations put on these sites. Users (oil and gas) must now conduct site impact assessments for Short-horned Lizards and undertake mitigation (Powell and Russell 1993a).

Populations found within or close to urban areas in Alberta and Saskatchewan are few. The population in Medicine Hat is probably almost or entirely gone, due to urban growth north of the South Saskatchewan River. That at Redcliff is found on a yet undeveloped area and could benefit from protection of its habitat along the river, especially as the entire Medicine Hat region is rapidly becoming urbanized. Similarly, projects affecting the rims of Chin Coulee north of Foremost should be evaluated for their effects on the phrynosome populations found there. Even with such measures, however, populations very close to urban development are susceptible to the depredations of small children and cats, neither of which are deterred by a species' legal status (Powell and Russell 1993a).

There is not enough information on Saskatchewan populations to make an evaluation that would add to the policies already in effect. The proposed Grasslands National Park includes almost all known localities within its boundaries (Powell and Russell 1996c*, 1996d*), and with proper range management (Reynolds 1979) the populations therein face no real threat.

The distribution in both Alberta and Saskatchewan is restricted to particularly favourable localities within the short-grass prairie. Population densities, being typical of those of phrynosomes in general, are low even within suitable areas, and, as recruitment also appears to be low, this form warrants recognition as a species of concern. However, it is protected in Alberta and Saskatchewan, and the habitat of some populations is protected by parks. Therefore, a COSEWIC status of Vulnerable seems the best designation in Canada at the present. Future development of the areas where it occurs would probably necessitate a re-evaluation its status.

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Productivity, Population Trend, and Status of Northern Goshawks, *Accipiter gentilis atricapillus*, in Northeastern Wisconsin

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Until the late 1960s, Northern Goshawks, *Accipiter gentilis atricapillus*, were considered rare breeders in Wisconsin. Research initiated in 1971 revealed a small but growing breeding population, which continued to increase until the mid-1980s when depredations by mammalian predators began to reduce numbers. Since 1985, reproduction has fallen below the estimated threshold of 1.7 young fledged/active nest needed to maintain a stable population. The reintroduced Fisher, *Martes pennanti*, is largely responsible for increased nest failure and adult female mortality, with the turnover rate of nesting females having doubled to over 40%. Twenty-two years of reproductive data reveal a correlation between population levels and the 10-year wildlife cycle. The goshawk has been listed as a "sensitive species" since 1986 in the Nicolet National Forest, and guidelines have been established for nest site protection. However, no such standards exist for state, county and private lands, where populations are declining. Legal and illegal "take" of nestling goshawks is a continuing concern, especially as nest sites under national forest management become more vulnerable to falconers, who have taken an estimated 5% of young from monitored nests.

Key Words: Northern Goshawk, *Accipiter gentilis atricapillus*, productivity, 10-year cycle, population trend, territory longevity, model, Fisher, *Martes pennanti*, predation.

The Northern Goshawk *Accipiter gentilis atricapillus* was considered a rare summer resident in Wisconsin since at least the middle of the 19th century (Kumlien and Hollister 1903). By 1900, most of the climax forests of mixed northern hardwoods, White Pine, *Pinus strobus*, and Red Pine, *Pinus resinosa*, had been logged and repeatedly burned. Goshawks in northeast Wisconsin probably persisted in uncut, unburned refugia, such as the 930 km² Menominee Indian Reservation. August Schoenebeck (1902: Kiff, personal communication 1983) documented the state's first nesting records in Oconto County near the reservation with the collection of four egg sets between 1885 and 1902. From then until 1968 there were only 10 additional nesting territories recorded, all in five northern counties (Robbins 1991).

The discovery of five nests, by Erdman, and Gary Jolin of the Wisconsin Department of Natural Resources (WDNR), in Oconto, Forest, and Marinette Counties in the late 1960s, initiated the study being reported. One territory located in 1968 in the Nicolet National Forest (NNF) was still active in 1993.

The objective of the project, initiated in 1971, was to investigate Goshawk population ecology, particularly predator/prey relationships, habitat uti-

lization and effects of forest management. The Goshawk research was part of a larger, long-term project which also included monitoring Broad-winged Hawks, *Buteo platyterus*, and Red-shouldered Hawks, *Buteo lineatus*. The project was entirely self-funded, and pursued on extended week-ends and/or while investigators were on annual leave. The rarity of Goshawk nest sites constrained the choice of available methodologies and made systematic search of the entire study area for nests impractical. We believe these Goshawk data provide a reasonably random sample and reflect overall conditions in Wisconsin. We follow the definitions of Postupalsky (1974) for breeding territory (hereafter territory), nest, active nest and successful nest. An active nest is one in which at least one egg is laid and a successful nest is one from which at least one young was fledged.

Study Area

The initial study area was 600 km², in Oconto, Forest and Marinette Counties, but because of the rarity of breeding territories it was expanded to 12 northeast and north-central counties including the Door Peninsula (Figure 1). The area involved is all of northeastern Wisconsin north of 44°30'N, and east of 90°W, including the entire 2650 km² NNF,



FIGURE 1. Location of the study area in northeastern Wisconsin and the southern extent of continuous northern forest in Wisconsin.

with the exception of the Menominee Indian Reservation. Except for the reservation, most of this area was logged and repeatedly burned prior to 1900. Poor soils and a short unpredictable growing season made attempts to farm cleared lands largely unsuccessful, resulting in much of the land being vacant and tax-delinquent by the 1920s. Large tracts were converted to public ownership as federal, state and county forest lands. Aspen, *Populus tremuloides*, and Paper Birch, *Betula papyrifera*, predominate, along with short-rotation Red Pine, *Pinus resinosa*, and Jack Pine, *Pinus banksiana*, used for paper production. Continued demand for pulpwood coupled with increasingly mechanized harvesting methods favors clear-cutting of large uniform blocks up to 259 ha in size. At present, much of the county and private forest land is already in the second or third rotation of aspen/birch regeneration. Selectively logged stands are succeeding to shade-tolerant Red

Maple, *Acer rubrum*, Sugar Maple, *Acer saccharum*, Balsam Fir, *Abies balsamea*, and Eastern Hemlock, *Tsuga canadensis*. The Door County peninsula is an exception to this pattern, as the climate moderation of Green Bay and Lake Michigan make it ideal for orchards and tourism. Much of the sub-boreal forest bordering the Lake Michigan shoreline is still intact. Due to a tremendous tourism industry, logging is almost nonexistent there and several relatively large state parks harbor mature maple, Beech, *Fagus grandifolia*, and hemlock forests. For detailed information on the climate, geology and biota of the study area see Curtis (1959) and Robbins (1991).

Methods

Territory Activity

New territories were located by searching suitable habitat and through a network of contacts that included U.S. Forest Service, Wisconsin DNR, log-

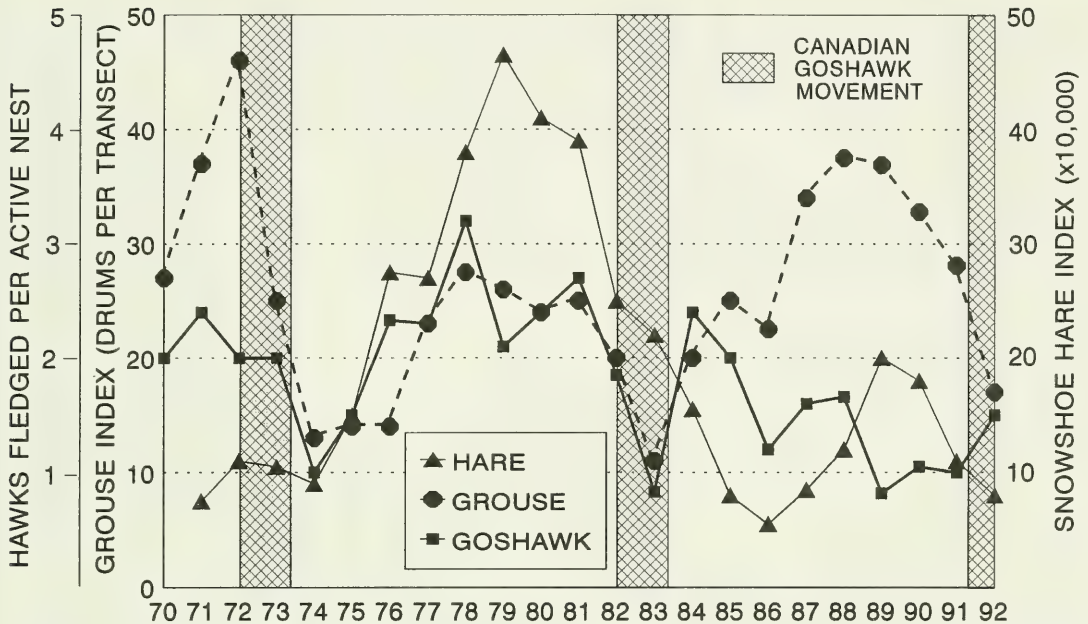


FIGURE 2. Ruffed Grouse index, Snowshoe Hare index and Northern Goshawk reproductive success in northeastern Wisconsin between 1970 and 1992.

gers, trout fishermen, falconers and bird watchers, as well as other interested individuals. In 1986, the Goshawk was listed as a sensitive species on NNF, requiring nest site protection. We conducted workshops and field training in identification of woodland raptor nests for NNF personnel. As a result of their interest and cooperation, the number of known territories on NNF has since doubled. The level of effort expended to verify territory activity varied between years, but has increased each year as more known territories were identified.

Beginning in March of each year, all known territories were checked for activity. When territories were abandoned, we continued to search them each spring until all old nest structures disappeared or substantial habitat changes occurred; e.g., logging or development. Time spent assessing individual territories each spring varied from as little as 15 minutes to as much as 12 person-days per site, depending upon activity. Typically, one researcher would examine the nest with binoculars from several vantage points to ascertain status. If an adult was not present at the previous season's nest or known alternate sites, an extensive search was conducted for a new nest. The small number of nesting territories allowed time for repeated thorough ground searches of surrounding habitat for a new nest up to a 1-km radius from the original nest location. This distance exceeds the greatest separation that we observed between any pairing of alternate nests within a territory.

To prevent desertion during incubation we did not climb nest trees and we have been very cautious about flushing incubating birds. In 1988, because of an increase in nest failure from mammalian depredation, we began placing greased metal baffles (1 m tall) around nest trees at banding time. However, because of continued serious nest failures during incubation, in 1992 we began installing these guards midway through incubation. This has improved reproductive success without resulting in increased abandonment.

Trapping and Banding

We did not attempt to trap adults until the young were at least 10 days old. In the early 1970s we used bal-chattris baited with Gerbils, *Meriones unguiculatus*, Starlings, *Sturnus vulgaris*, or feral Pigeons, *Columba livia*, and dho-gazas adjacent to a live or mounted Great Horned Owl, *Bubo virginianus*. In 1975 we switched to the use of two mist-nets (121 mm mesh, 210 denier), a live owl and a cassette tape recorder playing Goshawk vocalizations. The latter technique was extremely effective, allowing us to examine and mark 100% of the females and 60% of the males at successful nest sites in most years. In addition, mist-net use provided added protection to both Goshawks and the lure owl by preventing grappling which is dangerously uncontrollable with a dho-gaza set. Mist-nets also allowed for double catches when both adults were present. Typically however, the female was trapped first and later the

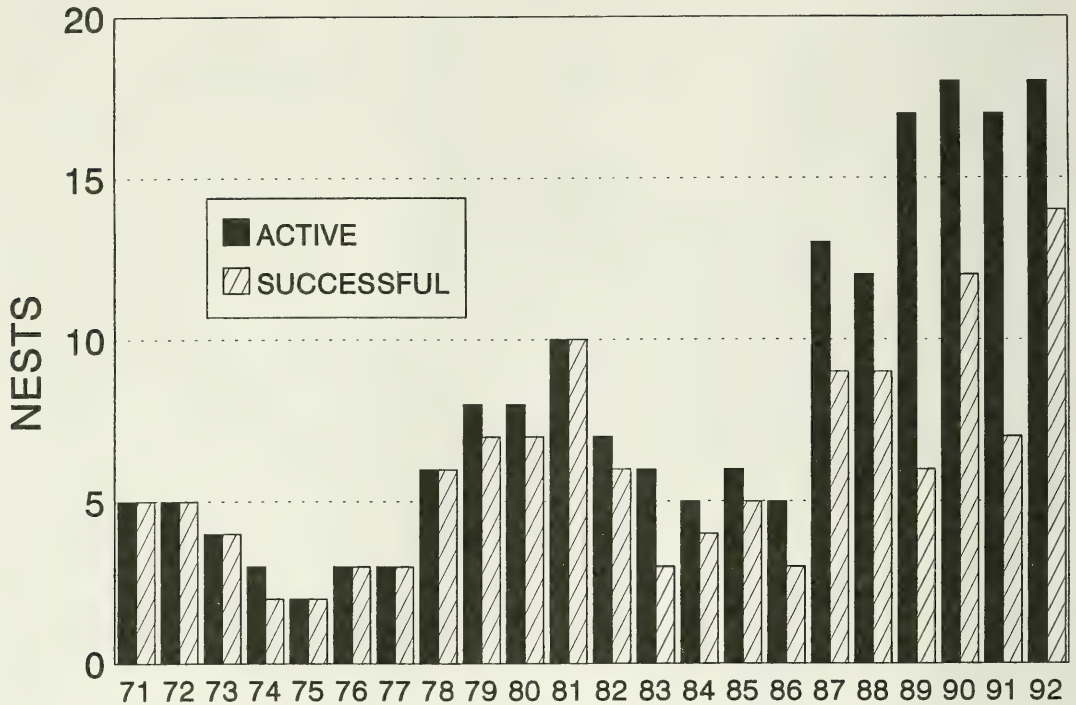


FIGURE 3. Variation in the numbers of active and successful Northern Goshawk nests monitored each spring during 1971–1992 in the northeastern Wisconsin study area.

male on his return with prey. The adults were held in appropriate holding tubes while the nest tree was climbed and the young banded. Adults were aged, sexed, weighed, measured, and marked with U.S.F.W.S. bands before release. A third visit was made to a territory post-fledgling to assess chick survival.

Snowshoe Hare, Ruffed Grouse and Fisher Population Estimates

Because both the quantity of prey available and presence of significant predators affect Goshawk population trends, we used data made available from WDNR's Bureau of Wildlife Research on the relative size of Snowshoe Hare, *Lepus americanus*, Ruffed Grouse, *Bonasa umbellus*, and Fisher, *Martes pennanti* populations through the years. For prey species we utilized the mean number of drums/transect from the spring drumming counts taken in northern Wisconsin as an index of breeding densities and population size for Ruffed Grouse, and the annual hunter harvest of Snowshoe Hare as an index of hare abundance (Figure 2). Collection of prey remains and pellets from plucking perches and nest sites has shown the two main prey items to be Snowshoe Hare and Ruffed Grouse, although many other species are also taken (unpublished data). To evaluate the relationship between Goshawk reproductive success and prey densities, an index of prey

availability was constructed from the WDNR data, with Prey Index = (Snowshoe Hare index²* Ruffed Grouse index)^{1/3}. The index was weighted towards Snowshoe Hares because hares weigh approximately 2.7 times more than Ruffed Grouse and represent a greater return on foraging time investment. The cube root was used to return the index value to the range of the primary index values.

WDNR Fisher population estimates were based on age and sex ratios, presence of corpora lutea and placental scars of harvested animals and Winter Furbearer Track Counts (Kohn et al. 1992). Additional information was obtained from Jon Gilbert, Great Lakes Indian Fish and Wildlife Commission biologist, who is engaged in long-term telemetry studies of Fisher in north-central Wisconsin.

Statistical Methods

To test for differences between two means we used *t*-tests. ANOVA and the Student-Newman-Keuls test for mean separation were used to test for differences between more than two means. Simple linear regression was used to test for the relationship between prey-index value and Goshawk reproductive success (young fledged per active nest). The alpha level used for rejection of all null hypotheses was $\alpha = 0.05$. All statistical analyses were performed using SAS statistical package (SAS Institute Inc. 1987).

TABLE 1. Distribution by forest ownership of Northeastern Wisconsin Northern Goshawk breeding territories.

Forest Ownership	Territories	Currently Active (%)	Logged (%)	Occupied by Great Horned Owls (%)
County	16	2 (13)	10 (63)	4 (25)
Private	16	3 (19)	8 (50)	2 (13)
Nicolet National Forest	40	17 (43)	14 (35)	3 (8)
State	5	3 (60)	2 (40)	1 (20)
Totals	77	25 (32)	34 (44)	10 (13)

Results

Territory Activity

Of the 77 territories found between 1968 and 1992, 8 were inactive when found, apparently abandoned due to logging, and 69 provided reproductive information. Between 1968 and 1992, 270 years of territory histories were collected, with the total of known nesting territories growing from 5 in 1971 to 69 by 1992. In 1992 at least some degree of activity was observed in 25 territories. Through the 22 years from 1971 through 1992, 181 active nests were found, ranging between 2 in 1975 and 18 in 1990 and 1992 (Figure 3). The number of active nests declined approximately 50% during each of the two most recent prey population declines (Figure 2 and 3). The average distance between nest clusters defining the centers of adjacent active territories was 8.8 km, with a minimum of 1.6 km being observed three times, all during years of peak prey densities.

Mean breeding territory longevity was 3.9 years, with ranges of 1 to 26 years. As of 1992, selective or clear-cutting within 100 m of nests had occurred at 34 territories [44% of the total and 65% of the inactive territories] (Table 1). Territory longevity was significantly greater on state-owned lands, 10.2 years, than all of the other categories; and shortest on county forest land, 2.4 years (Table 2).

Productivity

Goshawk reproduction between 1968 and 1992 is summarized in Table 3. Overall productivity in this 25-year span was 1.6 young fledged per active nest and 2.1 young fledged per successful nest. Before

1982 in only 3 of the 11 years were there failures of active nests, with 54 of 57 (94.7%) being successful (Figure 3). Significantly, in 1982 to 1992, nest failures occurred *every* year, and only 78 of 124 (62.9%) succeeded, with over half failing (21 of 34 (62%)) in 1989 and 1991 (Table 3).

Annual productivity, measured as young fledged per active nest, ranged from a 1978 high of 3.2 ($n = 6$ nests) to lows of 0.8 in 1983 and 1989 ($n = 6$ and 17 nests, respectively) and was directly correlated to the prey index ($P = 0.0097$, adjusted $R^2 = 0.243$) (Figure 2). The number of young fledged per successful nest was equal to the number fledged per active nest, except for three years, prior to 1982. In contrast, every year from 1982 through 1992 the number fledged per successful nest has been lower than the number fledged per active nest (Figure 4). This pattern of diminished success became pronounced starting in 1983 and became most apparent from 1988 through 1991 when a severe drought combined with an outbreak of Forest Tent Caterpillars, *Malacosoma disstria*, led to defoliation of trees in the study area.

Most if not all of the productivity loss was the result of Fisher predation, mainly during incubation (Figure 3). During this time, turnover rates, based on recapture and recovery data for breeding females, doubled. In 1990, we recovered the carcasses of four breeding females at nest sites ($n = 17$ nests). All had been killed and consumed by Fishers.

The number of young birds taken by falconers from the monitored nests was substantial (5%) and female-biased. The known annual take by falconers varied from a low of 0 to a high of 17% in 1979.

TABLE 2. Northeastern Wisconsin Northern Goshawk breeding territory longevity by forest ownership.

Forest Ownership	Territories	Territory Years	Years Active (Range)	Mean Longevity*	Still Active in 1992 (%)
County	15	36	1 - 5	2.4 ^a	2(13)
Private	15	59	1 - 10	4.0 ^a	3(20)
Nicolet National Forest	34	124	1 - 26	3.7 ^a	17(50)
State	5	51	2 - 17	10.2 ^b	3(60)
Totals	69	270	1 - 26	3.9	25(36)

*Means with different superscripts were significantly different (ANOVA, $F = 5.358$, $P = 0.002$).

TABLE 3. Northern Goshawk reproductive success in northeastern Wisconsin for time periods between 1968 and 1992.

Time Period	Nest Attempts	Successful Nests	Percent Successful	Young Fledged	Young Fledged/ Active Nest	Young Fledged/ Successful Nest
1968-1992	184	135	73	288	1.6	2.1
1968-1992 ¹	184	138	75	304	1.7	2.2
1971-1981	57	54	94 ²	122	2.1 ³	2.3
1982-1992	124	77	62 ²	160	1.3 ³	2.1

¹ Includes young taken for falconry, n=16.

² Significantly different (t-Test, t=4.857, P<0.001).

³ Significantly different (t-Test, t=3.044, P=0.006).

Prey populations

Snowshoe Hare and Ruffed Grouse population fluctuations for the period 1970-1992 are shown in Figure 2. The conspicuous 10-year cyclic fluctuations from peaks to valleys of these two sympatric species were apparently linked (Keith 1963; Rusch et al. 1978). Although they showed considerable synchrony, it was also obvious that their population amplitudes varied between 10-year cycles in both magnitude and in the timing of analogous phases of the cycle. Wisconsin hare and particularly grouse populations are directly affected by the periodic autumn "invasions" of Canadian Goshawks following hare population crashes farther north (Keith and Rusch 1988). Major invasions, each exceeding 5500 individuals, were documented in 1972 and 1982 at Hawk Ridge, Duluth (D. L. Evans, personal communication.).

Fisher Populations

Prior to settlement by Europeans, Fishers were common in heavily forested areas of Wisconsin. Deforestation and fur-trapping drastically reduced the population by the end of the 19th century (Petersen et al. 1977), and the population was considered extirpated by the 1930s. In 1956, WDNR, in cooperation with the U.S. Forest Service, initiated a Fisher reintroduction project, with 60 animals being released in closed areas of the NNF through 1963. Fishers are now common throughout northern Wisconsin, with sightings reported south to near the limits of the continuous forest in Adams, Manitowoc, and Winnebago Counties (Figure 1).

Population analyses by Kohn and Ashbrenner (1992) showed a steadily increasing number of Fishers, from an estimated 2650 in 1977 to 6000 by 1992. Based on model simulations and track-count analysis, Kohn and Ashbrenner assumed a density of one Fisher per 6.5 km². Jon Gilbert (personal communication) has documented, by trapping, Fisher densities exceeding one animal per 2.5 km² on the Chequamegon National Forest in north-central Wisconsin. During the winter of 1992-1993 the trapping season was liberalized and over 1600

Fishers were taken (R. Eckstein, personal communication). The relative frequency of Fisher tracks on the 1992-1993 Winter Furbearer Track Counts was 4.8, up 25% from the previous winter, and almost double the 2.5 from the 1990-1991 survey (B. Kohn, personal communication). This increase occurred despite a ten-fold increased harvest during 1992-1993. Recent, revised DNR estimates now suggest that 10 000 Fishers were present in 1993 (Kohn and Ashbrenner 1993).

Discussion

Productivity

Goshawk productivity and nesting densities have been correlated to fluctuations in prey densities, mainly tetranoid populations in northern Europe (Hoglund 1964; Huhtala and Sulkava 1981; Wikman and Linden 1981), and Snowshoe Hares in Alaska (McGowan 1975) and the Yukon (Doyle and Smith 1994). Annual productivity in northeastern Wisconsin Goshawks was similar to the values reported in other North American studies and is directly correlated to regional densities of Snowshoe Hares and Ruffed Grouse (Figure 2). In a four-year study by McGowan (1975) in Alaska, the number of young fledged per active nest varied between 1.8 and 2.5. The number of active nests in his study area declined from 9 to 1, with the low occurring in 1974 corresponding to the Wisconsin low during that prey cycle. Overall production in Alaska was 2.0 young fledged per active nest (McGowan 1975). The highest reported annual reproduction in North America was recorded in the Yukon, 3.9 young fledged per active nest in 1990 (Doyle and Smith 1994), 19% higher than we observed in peak years. This high productivity was quickly followed by a decline to 1.3 young fledged per active nest the following year, and no young in 1992. Overall production in their four-year study was 2.3 young fledged per active nest (n = 19) and 3.1 young per successful nest (n = 14).

Doyle and Smith also reported a dramatic decline of active nests exceeding 80%. Active nests in

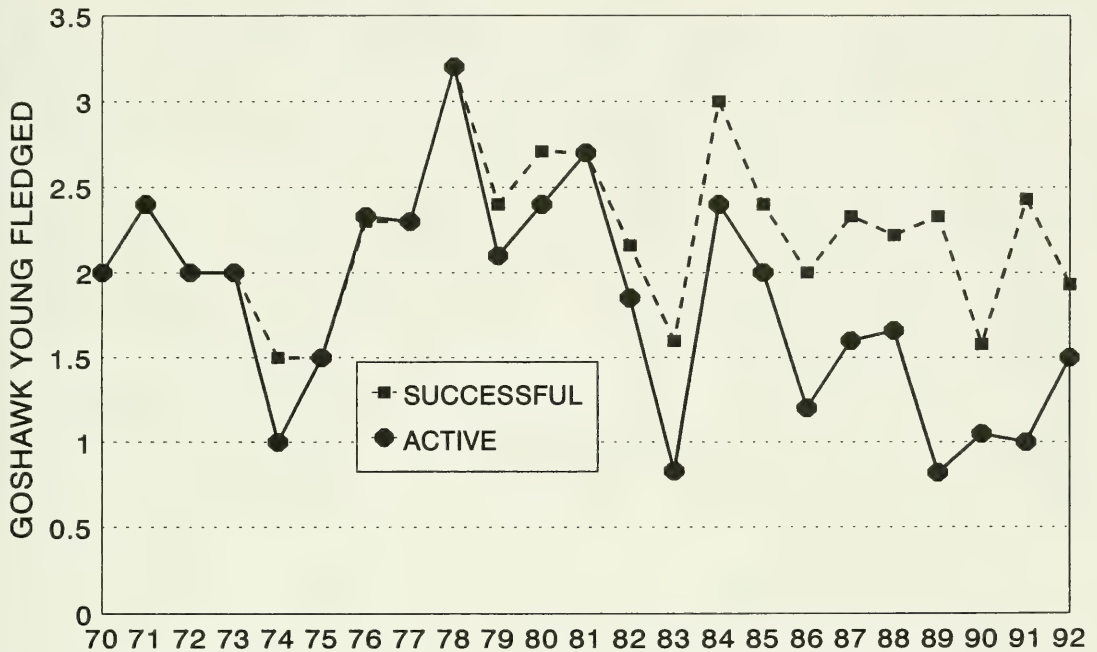


FIGURE 4. Variation in productivity between active and successful nests of Northern Goshawk in northeastern Wisconsin during 1971–1992.

Wisconsin have declined by only 50% in each of the two most recent cyclic lows, possibly due to the availability of alternate prey species at our more temperate latitude. Wisconsin Snowshoe Hare populations in comparison to Canadian populations have been only “weakly cyclic” since the 1930s, apparently as a result of fire suppression and habitat maturation and fragmentation (Buehler and Keith 1982). The similar wide annual variations in productivity in Alaska, Yukon and Wisconsin appear to be correlated with the dramatic variations in prey density. We suspect, based on the reported severe declines in the numbers of active nests, that the northern populations are much less stable on a regional scale than the Wisconsin population. Jerry McGowan (personal communication, 1993) noted that neither Snowshoe Hare nor Goshawks ever again reached the high population level or cycled on his 1970s Alaskan study area. The more northern populations are Snowshoe Hare obligates (Keith 1977), and interior Canadian and Alaskan Goshawks exceed Wisconsin birds in both size and mass (Erdman and Brinker, unpublished data). Cyclic declines of Snowshoe Hares in the northern forests have triggered invasions of Goshawks into southern areas (Mueller and Berger 1967; Mueller et al. 1977). In Wisconsin, we have not documented any movement of our marked adult Goshawks out of their breeding range. This 10-year pattern of cyclic productivity has also been documented in

Alberta for Red-tailed Hawks, *Buteo jamaicensis* (McInville and Keith 1974) and Great Horned Owls, *Bubo virginianus*, in Alberta, Saskatchewan and Manitoba (Rusch et al. 1972; Houston 1978; Adamcik and Keith 1978; Adamcik et al. 1978). This is in contrast to the relatively stable productivity exhibited by Goshawks in the western states. In a six-year Oregon study, Reynolds (1978) reported 2.3 young fledged per successful nest ($n = 25$) and 1.7 young fledged per active nest ($n = 48$). This is remarkably similar to 2.1 young fledged per successful nest ($n = 135$) and 1.6 young fledged per active nest ($n = 184$) reported in this study (Table 3).

We have observed a significant change in northeastern Wisconsin Goshawk productivity over the 1971–1992 period (Table 3). From 1971 to 1981 nest success was high at 94%. Between 1982 and 1992, the overall nest success in northeastern Wisconsin fell to 62%. The primary cause of the increased nest failure was Fisher predation during incubation.

In northeastern Wisconsin prior to 1985, nest failures were infrequent, and occurred mainly in the southern portion of the study area where Great Horned Owl and Raccoon, *Procyon lotor*, were more abundant. Now more nests are lost in the north, where the dominant predator is the Fisher. Obviously Fishers and Goshawks co-exist over vast expanses of Canada, and historically they did so in Wisconsin. We can find no records in the literature of Fishers taking nesting adult Goshawks in North

America. It is probable that the extensive, continuous, mixed hardwood and conifer forests which existed prior to settlement, provided more concealed (optimal) sites which protected the nests from destruction. Current forests are often composed of monotypic stands of Aspen, Paper Birch, and pine; the two former species in particular providing more exposed nest sites. An example of the effect of loss of nest cover occurred in 1989, when 66% of the Goshawk nests were lost when Forest Tent Caterpillars defoliated deciduous trees. During that same year, 18 of 19 Red-shouldered Hawk nests were also lost to predation. Another possible factor leading to increased predation is the concentration of both Fishers and hawks in the same habitat due to forest fragmentation, created by the clear-cutting of large tracts. Carcasses and gut piles left by hunters of Wisconsin's estimated 1.5 million White-tailed Deer, *Odocoileus virginianus*, also provide Fisher with excellent overwinter survival rates.

Population Model and Trend Analysis

In 1979, to estimate yearly changes in the population and evaluate long term trends, we developed a population model for northeastern Wisconsin Goshawks (presented at 1980 American Ornithologist's Union meeting, Fort Collins, Colorado). The model assumed a population with all adults, at least 24 months old and 10% of one-year-old birds attempting to breed, with a nesting success rate of 75%. In northeastern Wisconsin the proportion of one-year-old females breeding in any given year has never exceeded 20%. Most one-year-old males are apparently incapable of breeding (Cramp and Simmons 1980; Glutz et al. 1971) and we have never encountered males entering the breeding pool before the age of 24 months. The 10% (above) was calculated as a proportion of the juveniles surviving from the previous year. We assumed 65% first-year mortality and an equal sex ratio. Adult mortality was assumed to be 20% annually. The adult mortality rate was based on turnover rates of adults in established territories as measured from our recapture and band recovery data. The model required 1.7 young to be fledged per nesting pair to maintain a stable population, a value very similar to the overall mean number of young fledged per active nest in northeastern Wisconsin. Population trends were simulated by using the observed annual productivity and nest success as measured in our study area for 1971 through 1992 (Figure 5).

The model showed increasing Goshawk populations from 1971 through 1986. The simulated population doubled by 1981, then declined by 34% during the periodic low of the 10-year population cycle in 1983, but was able to recover by 1985. Since then a gradual decline has decreased population values to the initial 1971 level in 1991.

Increasing the adult mortality to 25%, reflecting an additional 5% loss to Fisher for all years after 1984, we observe an overall population decline to 14% below the 1971 level (Figure 5). The number of breeding pairs mirrored this pattern, with an expected two-year time lag for juveniles to move into the breeding population.

The results of our population simulation agree with this general impression of an increasing population expanding southward between 1971 and 1985. A similar trend has been noted in the lower peninsula of Michigan (Sergej Postupalsky, personal communication; Brewer et al. 1991). These increases could reflect improving habitat conditions as regenerating northern forests mature. The significant changes in reproductive success that occurred during the late 1980s are cause for serious concern. The changes in reproductive success reversed the trend of the model population and produced a steeper decline from 1986 to 1992 than the 1971 to 1985 increase.

The observed increase of the adult female turnover rate to 40% since 1987 which we attribute to mortality, is the most important parameter impacting the population. Recapture and recovery data, prior to the Fisher predation, indicated that adult male Goshawks were surviving approximately 25% longer than adult females. If, indeed, females have a shorter life span, the increased female bias predation will only result in an unbalanced sex ratio with an inevitable decline in Goshawk numbers. We are now recording previously active territories where only males are present. It should be noted that Fishers are highly territorial and vigorously recheck previous kill sites each time they pass through the area (Jon Gilbert, personal communication). If a male Goshawk, who has lost his mate to predation, attracts a new female to the territory and she reuses an existing nest platform that was previously predated by a Fisher, she also faces a high probability of nest failure and death. This recent phenomenon of nest failure and increased adult mortality has not been noted in the lower peninsula of Michigan where Fisher are absent and Goshawks continue to expand southward (Postupalsky 1993, and personal communication).

Territory Longevity

In northern Wisconsin current forest management practices have often adversely affected Goshawks and other woodland nesting raptors such as the state threatened Red-shouldered Hawk. It has been our experience that large clearcuts typical of county and some commercial forests allow Red-tailed Hawks and Great Horned Owls to move into an area and displace the woodland hawks. We have witnessed owl predation on Goshawk nestlings, fledged young and adults. This pattern of displacement by owls in relation to forest ownership and logging is apparent in Table 1. Selective cuts adjacent to clearcuts or

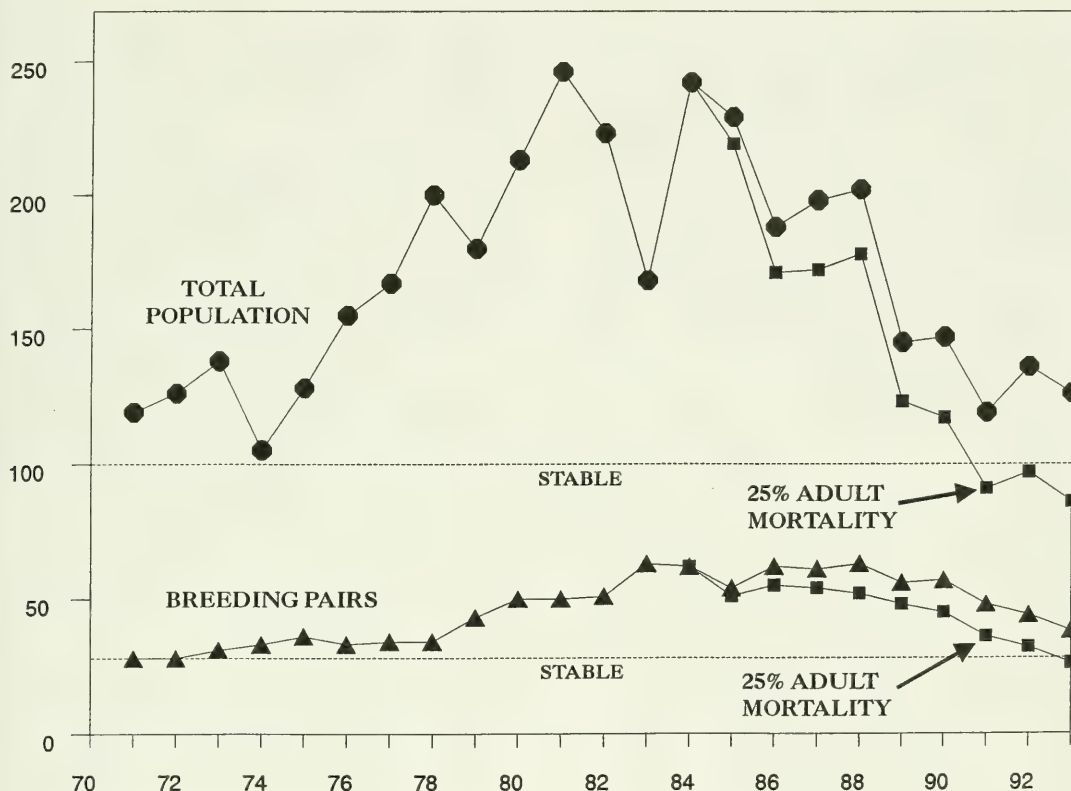


FIGURE 5. Modeled population trend of Northern Goshawks in northeastern Wisconsin from 1971-1992.

natural openings that open the canopy over 40% have the same effect. NNF, which has had the least percentage of territories occupied by owls (8%), has a moratorium on any clearcuts exceeding 16 ha in size. The different average rotation period of Aspen-Birch stands on NNF, 40-60 years, and county forest, 30-45 years, results in earlier logging of Goshawk nest sites on county forest land. The shorter rotations used on county forest lands effectively limits the "window of opportunity" for Goshawks attempting to utilize maturing Aspen-Birch stands as nest sites (Table 1). The effect of forest management is apparent in Goshawk territory longevity (Table 2). Territories have seldom persisted over five years on county forest lands while a site on NNF, where management practices are markedly different, has lasted over twenty five years. The highest mean territory longevity (10.2 years) occurred on state owned lands. Two of these territories were located in large forested state parks where no logging occurred. Notably, average territory longevity in Wisconsin was 3.9 years with a range of 1 to 26 years. Speiser (1991), reported an average occupancy of 3.83 years with a range of 1 to 8 years in New Jersey and New York.

Status and Conservation Needs

Our main concern for the Wisconsin Goshawk population is the lack of a statewide forest management plan with mandatory nest site protection guidelines for woodland raptors. NNF is the only Great Lakes States national forest to have established and implemented nest management guidelines for Goshawks and Red-shouldered Hawks. These guidelines require road closure and a 8 ha buffer around a nest. Only limited selective cutting is allowed around the buffer. NNF also has a moratorium on any clearcuts exceeding 16 ha in size and the cutting of White Cedar, *Thuja occidentalis*, and Eastern Hemlock is also prohibited. These guidelines, established in 1986, have yet to be evaluated. However, currently 70% of our active territories are on NNF. Effective evaluation will be complicated by the problem of increased Fisher predation.

Another negative pressure on the population is the legal and illegal "take" of nestling Goshawks by falcons. Over the 22-year period of our study the effect of falcons removing young has reduced the mean reproductive success by one tenth (Table 3). Unfortunately, due to poor state regulation and inadequate state and federal record keeping, it is

almost impossible to determine the number of Goshawks harvested annually.

It is very difficult to assess the population status of Goshawks in Wisconsin in terms of abundance and density. Territories are widely dispersed, nonrandomly, and undergo fluctuations of up to 50% through the 10-year prey cycle. Current forestry often produces rapid habitat changes. Recent increases in adult mortality and decreases in productivity are of concern and need to be further monitored. Landscape scale management of Wisconsin's forests is needed to provide for the habitat needs of Goshawks.

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Observations of White Whales, *Delphinapterus leucas*, in Waters off Newfoundland and Labrador and in the Gulf of St. Lawrence, 1979–1991

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Thirty-seven sightings, strandings and gear entrapments of White Whales (*Delphinapterus leucas*) made in Newfoundland and Labrador waters and the lower Gulf of St. Lawrence from 1979 to 1991 are reported. Most of these incidents occurred in the summer months with a mean rate of 2.6 records per year. Fourteen (38%) of the observed animals were dead when discovered; fates of the remaining animals were not recorded. Toxicological analysis of one animal indicates that it was from an Arctic or Subarctic population. The stock affinities of the other animals were uncertain.

Key Words: White Whale, *Delphinapterus leucas*, cetacean, Newfoundland, Labrador, Gulf of St. Lawrence.

The White Whale or Beluga (*Delphinapterus leucas*) is a member of the cetacean family *Monodontidae*. Its habitat is north circumpolar ranging into the Subarctic. The world population of White Whales is estimated to be 88 000 – 114 000 animals and is subdivided into at least 16 stocks that are isolated from one another to varying degrees (IWC 1992). Seven White Whale stocks are provisionally recognized in Canada: Beaufort Sea-Mackenzie Delta, High Arctic, Southeast Baffin, Ungava Bay, East Hudson Bay-James Bay, West-South-North Hudson Bay and St. Lawrence River (IWC 1992).

Occasional sightings and strandings of White Whales in the western Atlantic Ocean have been recorded far south of their usual habitat. Reeves and Katona (1980) reviewed extralimital records of White Whales in eastern North American waters during the period 1675–1979. A total of 31 records in the Canadian Maritimes and the New England states were described. Mercer (1973) mentions a White Whale that lived through spring to fall in Bonavista Bay, Newfoundland in 1972. This paper summarizes sightings, fishing gear entrapments and strandings of White Whales in the waters of Newfoundland and Labrador and the lower Gulf of St. Lawrence during the period 1979–1991.

Methods

Reports of fishing gear entrapments, strandings and sightings of White Whales in Newfoundland and Labrador were received through sighting programs operated by the Whale Research Group and the Department of Fisheries and Oceans - Newfoundland Region (DFO).

The Whale Research Group maintains a provincial Entrapment and Stranding Network and an extensive sighting network. Several agencies,

including the Department of Fisheries and Oceans, the Newfoundland and Labrador Department of Fisheries and the Canadian Coast Guard, referred reports of cetaceans to the Entrapment and Stranding Network. A full description of the Network is available in Lien (1994). Weekly reports of cetacean sightings were also received from land-based observers from 120 locations around the province; many of these observers were Canadian Coast Guard lighthouse keepers (Lynch 1987). DFO received periodic sighting reports from shipboard observers on inshore and offshore research vessels, as well as occasional reports from fishermen.

Reports of sightings and strandings of White Whales from the waters of the Gulf of St. Lawrence were also received from the Prince Edward Island Stranding Network, Prince Edward Island Department of Fisheries and Aquaculture, Grand Manan Cetacean Research Station in New Brunswick and the St. Andrew's Marine Laboratory in New Brunswick.

Results and Discussion

Thirty-three records of White Whales in the waters of Newfoundland and Labrador and four records from the lower Gulf of St. Lawrence were reported from 1979–1991 (Table 1). Ten animals were entrapped in fishing gear and most of these animals (90%) were dead when discovered. Five of the non-entrapped White Whales reported were found either stranded or floating dead. Locations of records are shown in Figure 1.

The frequency of White Whale records ranged from zero to eight animals per year, with a mean rate of 2.6. Sighting rates were somewhat higher from 1988–1991 (mean = 5.2 animals per year), possibly as a result of colder water temperatures

TABLE 1. Sightings, strandings and fishing gear entrapments of White Whales (*Delphinapterus leucas*) in Newfoundland and Labrador, New Brunswick, Prince Edward Island, and Nova Scotia. Localities not followed by a region are the island of Newfoundland, 1979–1992.

No.	Date	Latitude-Longitude	Location	Number	Comments
1	? July 1979	43°55'N, 59°50'W	Sable Island, Nova Scotia	1U	Observed swimming approximately 14 miles south of Sable Island
2	17 July 1979	46°59'N, 53°35'W	Mal Bay	1U	Caught in gillnets and killed; approximately 4.5 m long
3	24 June 1979	48°45'N, 54°W	Freshwater Bay	1F	Caught in codtrap; lactating, previously observed with calf
4	4 August 1979	46°45'N, 48°47'W		1U	Observed floating dead at sea
5	9 July 1980	52°22'N, 55°41'W	St. Lewis, Labrador	2U	Observed swimming near Lewis Bay
6	1 May 1981	49°56'N, 56°23'W	Seal Cove, White Bay	1U	Found dead in herring nets; approximately 5.5 m long
7	? June 1982	47°35'N, 56°45'W	Francois	1U	Swimming in vicinity of fin whale; approximately 6 m long
8	25–26 June 1982	49°36'N, 57°55'W	Rocky Harbour	1U	Sighted twice swimming in Bonne Bay; approximately 2.75 m long
9	31 August 1982	48°33'N, 58°44'W	Port au Port	1U	Stranded beluga examined by Fisheries Officer; 3.5 m long
10	30 June 1983	53°54'N, 57°49'W	Cape Porcupine, Labrador	1U	Sighted off Cape Porcupine by ship observer
11	24 August 1983	57°28'N, 62°20'W	Okak Bay, Labrador	1U	Killed and partially eaten by Orcas
12	18 June 1985	51°32'N, 56°50'W	L'anse au Loup, Labrador	1U	Caught in gillnets, live release; approximately 3.8 m long
13	16 April 1985	48°05'N, 53°01'W	Old Perlican	1U	Same animal sighted twice;
13	22 April 1985	47°41'N, 53°50'W	Chance Cove	1U	approximately 3.5 m long
14	27 May 1986	51°23'N, 55°30'W	St. Carol's	1U	Repeated sightings reported
15	31 May 1986	49°22'N, 55°29'W	Glover's Harbour	1U	Sighted near shore; may be same whale seen 27 May
16	10 July 1986	56°32'N, 61°41'W	Nain, Labrador	1U	Hunted and killed for food by local people
17	19 August 1986	48°33'N, 58°35'W	Stephenville	1F	Floating near Kippens River; approximately 6 m long
18	28 April 1988	46°25'N, 63°12'W	Brackley Beach, Prince Edward Island	1F	Found dead, emaciated; tissues analyzed? (Daoust, personal communication; Beland et al. 1992)
19	25 June 1988	49°36'N, 57°55'W	Rocky Harbour	1U	Swimming in Bonne Bay
20	? July 1988	46°32'N, 63°35'W	Sea View, Prince Edward Island	1U	Found dead, very decomposed
21	10 July 1988	49°50'N, 57°50'W	Gros Morne National Park	1F, 1U	Cow and calf sighted
22	14 July 1988	44°40'N, 66°50'W	North Head, Grand Manan, New Brunswick	1U	Live animal seen swimming in region for two weeks; disappeared
23	31 July 1988	47°40'N, 52°44'W	Torbay	1U	Swimming near Torbay
24	9 August 1988	51°06'N, 55°45'W	St. Julien's	1U	Found dead in fishing gear
25	2 May 1989	47°41'N, 53°50'W	Chance Cove	1F	Found dead in codtrap; teeth aged and tissue samples analyzed for contaminants (Beland et al. 1992)
26	12 May 1989	48°38'N, 53°03'W	Elliston	1U	Found dead in codtrap
27	12 May 1989	48°21'N, 53°23'W	Dunfield	1F	Died in codtrap; 3.43 m
28	13 June 1990	51°30'N, 55°29'W	St. Lunaire	1F	Found dead in lumpfish net
29	? June 1990	49°33'N, 54°52'W	Whales Gulch	1U	Beland et al., 1992
30	13 May 1991	49°09'N, 55°21'W	Botwood	1U	Sighted alive, disappeared
31	16 May 1991	49°30'N, 55°00'W	Exploits Island	1U	Swimming in bay, disappeared
32	20 May 1991	50°00'N, 56°20'W	Wild Cove	1U	Sighted alive, disappeared
33	14 July 1991	47°33'N, 54°54'W	Bay L'Argent	1U	Observed swimming near harbour
34	16–17 July 1991	47°36'N, 54°55'W	Harbour Mille	1U	Swimming in harbour; probably same animal observed in Bay L'Argent
35	7 August 1991	47°00'N, 52°58'W	Aquaforce	1U	Sighted acting strangely, disappeared
36	19 August 1991	47°32'N, 54°57'W	St. Bernard's	1M	Found dead in gillnet, had been seen alive in area previously; 3.7 m long
37	24 October 1991	54°54'N, 59°47'W	Postville, Labrador	1U	Swimming in bay outside town



FIGURE 1. Locations of White Whale sightings, 1979–1992.

(Mann and Drinkwater 1994). Most reports involved solitary animals. Two pairs of animals, including one of a cow and her calf, were reported.

Most records occurred during the months of May (24%), June (22%), July (27%) and August (19%) (Figure 2). A few records occurred during April (5%) and October (3%). No records were made during winter months. This seasonality may be the result of observer effort and/or pack ice conditions.

The factors that limit the numbers of White Whales in the waters of Newfoundland and Labrador are unclear. Reeves and Katona (1980) discussed four possible limiting factors in eastern North American waters, including water temperature, predator avoidance, food abundance, and feeding strategy and competition, and tentatively concluded that competition for food was the most important factor.

Water temperature and predation are unlikely limiting factors in Newfoundland and Labrador. Surface water temperatures seldom rise above 15 degrees even during summer and temperatures below the surface remain just above freezing (Mann and Drinkwater 1994). Killer Whales (*Orcinus orca*) and Polar Bears (*Ursus maritimus*), the only known predators of White Whales, are relatively rare in Newfoundland and Labrador (Lien et al. 1988).

Interspecific competition has often been suggested as a possible limiting factor at the margins of the White Whale's range (Reeves and Katona 1980; Finley, Hickie and Davis 1987; Reeves and Mitchell 1989). Harbour Porpoise (*Phocoena phocoena*), Atlantic White-Sided Dolphins (*Lagenorhynchus acutus*), White-Beaked Dolphins (*Lagenorhynchus albirostris*), Long-Finned Pilot Whales (*Globi-*

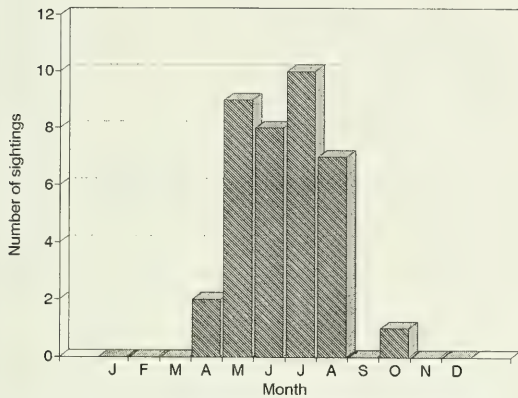


FIGURE 2. White Whale sightings by month, 1979–1992.

cephala melas), Harbour Seals (*Phoca vitulina*), Grey Seals (*Halichoerus grypus*), and, increasingly, Harp Seals (*Phoca groenlandica*) may be significant competitors for food. Competition for food by humans may limit White Whale numbers as the waters of the northwest Atlantic have been heavily fished for many years (Reeves and Katona 1980; Finley, Hickie and Davis 1987).

White Whales in the Arctic and Subarctic move into river estuaries in the summer months. Thus, another possible limiting factor may be the availability of suitable estuarine habitats in Newfoundland (Reeves and Mitchell 1989; Finley, Hickie and Davis 1987). Several theories have been proposed to account for this behaviour, including response to the movement of prey, and thermal advantages to calves and adults; however, no data support these theories (Watts, Draper and Henrico 1991). A more likely explanation for this behaviour is that the elevated temperature and low salinity of the estuaries assist the animals' annual molt and stimulate epidermal growth (St. Aubin, Smith and Geraci 1990). No data was available on the suitability of Newfoundland river estuaries for White Whales.

The stock affinities of the White Whales sighted in Newfoundland and Labrador are unknown. Although the nearest population of White Whales occurs in the St. Lawrence River, an analysis of blubber polychlorinated biphenyl (PCB) levels of the Whales Gulch animal showed that the animal was from an Arctic or Subarctic population (Beland, De Guise and Plante 1992). Continued monitoring of extralimital White Whales and toxicological tissue analysis may yield further information on their stock affiliations.

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Some Observations on the Natural History and Behaviour of the Canada Lynx, *Lynx canadensis*

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We made observations of Canada Lynx (*Lynx canadensis*) natural history during a long-term study of lynx population dynamics in southwest Yukon. We found evidence of adult lynx mating during Snowshoe Hare (*Lepus americanus*) population lows. We also found evidence of adult lynx litter sizes as large as eight and of adult and yearling lynx giving birth to kittens as much as six weeks later than normal, during hare highs. We document one instance in which a late-born litter of five survived to April when hares were abundant. We present evidence to suggest that some female lynx may lose their litters shortly after parturition during periods of food shortage. The above adaptations allow lynx the flexibility to respond demographically to changes in food supply faster than other species its size. We present evidence to suggest that the bond between related female lynx continues into their adult lives, as in other felids.

Key Words: Canada Lynx, *Lynx canadensis*, litter size, breeding behaviour, mating, predation behaviour, reproduction, social behaviour, vocalization, Yukon.

Our understanding of feline behaviour comes mainly from the study of captive animals or savannah dwelling species such as Lions (*Panthera leo*) and Cheetahs (*Acinonyx jubatus*). Behavioural observations of forest-dwelling felids are rare. Between December 1986 and June 1994 we made observations of Canada Lynx (*Lynx canadensis*) natural history, including behaviour, during a study of the population dynamics of an unharvested population in south-central Yukon (60° North, 135° West; Mowat 1993; Mowat et al. 1996; Slough and Mowat 1996).

The study involved live capture of all age classes during winter ($n = 161$ individuals) and neo-natal kittens in summer ($n = 185$ kittens from 39 litters), aerial and ground telemetry of radiocollared individuals, snow-tracking of family groups, and necropsy of carcasses collected from surrounding sub-populations (Mowat et al. 1996; Slough and Mowat 1996). The study area was > 70% regenerating boreal forest following a 1958 wildfire with scattered mature stands and alpine tundra throughout (Slough and Mowat 1996). The lynx population increased from a low of 2.7/100 km² in 1987 to a peak of 44.9/100 km² in March 1992, declined precipitously in fall 1992, and was at low levels again by 1994. Snowshoe Hare (*Lepus americanus*) numbers peaked in 1990 in our study area (Slough and Mowat 1996).

In this paper we summarize observations of reproductive, social and predatory behaviour that we made while conducting our study. We also include unusual observations of lynx and hares made by trappers and other members of the public from the region surrounding our study area.

Results

Reproduction

We saw male-female pairs of lynx together each year only during the breeding season (March–April). This occurred even during years when there was no evidence of kitten survival, indicating that breeding may have occurred, and that kits may have been lost in the pre-natal or early post-natal period. On 26 March 1992, we observed a radiocollared female lynx and two kittens with a larger adult, presumably a male. These four lynx were together for several days thereafter, suggesting that pair bonding persists for several days, and that at least some adults will tolerate kittens during breeding.

The average adult litter size as measured in the field was 5.1 during years of hare abundance (Mowat et al. 1996). We also found evidence of some very large litters. The uteri of two lynx collected adjacent to our study area in 1989–1990 each had eight recent placental scars. This was also the case for two other uteri from lynx collected 180 km north of the study area in 1989–1990, and a third collected 530 km northwest in 1986–1987. A trapper from northern British Columbia, 300 km east of the study area, trapped an adult female and five kits, while three kits were observed nearby in December 1990 (M. Fuller, personal communication).

The mean date of birth was 28 May for adults and 14 June for yearlings in our study (Mowat et al. 1996). Unusually small kittens were occasionally reported to us by trappers during this study and offer evidence of late breeding. A trapper cooperating on a test of lynx trapping systems 180 km north of

Whitehorse caught a yearling female (7.75 kg) and two 3.75 kg kits (a male and a female) at the same set within a 4-day period in January 1990 (J. Hofer, personal communication). Another kitten, caught 7 December 1988, weighed 3 kg, while another, captured 15 December 1988, weighed 3.5 kg. The latter two animals had been skinned, and therefore the live weight was at least 15% greater (R. Rivard, Wildlife Technician, Yukon Fish and Wildlife, unpublished data). Kits normally weighed >6.0 kg at this time of the year (Slough, unpublished data).

We do not know how long any of the above kittens would have survived. However, a female kitten born in July 1990 was captured in April 1991 weighing 5.5 kg. Most female kittens were > 6.5 kg by this age. There were at least five surviving kittens in the above litter in April which demonstrates that late born litters can survive through the winter when hare numbers are high.

Kitten Survival

When hare numbers were declining (1991-1993), many female lynx did not have a litter in June. We wanted to know if these females had failed to give birth or had lost their litters shortly after birth, in order to separate the effects of reproduction and kitten survival on population dynamics. We tested the hypothesis that movement patterns of females without litters were restricted during the parturition period (16 May-15 June). Previous work had indicated that females with litters reduced their movement distances markedly during the parturition period; their locations were confined to a very small area around the nest site (Mowat et al. 1996). We compared the distance between four locations (the average number we had for females during the parturition period) before the parturition period with four locations during the parturition period for all females that did not have a litter in 1991 and 1992. Movement distances may have been smaller during the parturition period than before during both years (1991, paired $t = 3.51$, $n = 10$ females, $P = 0.007$ and 1992, paired $t = 1.95$, $n = 9$ females, $P = 0.087$). In addition, seven of 10 females without litters in mid-June 1991 were located within a 0.25 km² area for at least three consecutive times during the parturition period. In 1992, four of nine females without litters were located within a 0.25 km² area for at least three consecutive times during the parturition period. The above evidence suggests that some females that did not retain litters to mid-June did give birth and therefore had lost the litters shortly after parturition.

Social Interactions

Like most other felids, lynx are generally solitary with the exception of mother-kit groups. We made several observations of interactions among adults. P. Henstridge (hiker, personal communication) observed an aggressive encounter between two lynx

in June 1991 near Beloud Post, 200 km west of our study area. The lynx were in a tall White Spruce tree (*Picea glauca*), each alternately advancing and retreating while vocalizing and swatting with forelimbs. They also leapt back and forth to another tall spruce 2 m away, while continuing to swat and vocalize. There was no apparent physical contact between the two and, even though we did not follow the incident to its conclusion, no sign of injury was observed at the site the next day.

Lynx kittens generally remain with their mother for about 10 months (Parker et al. 1983; Mowat et al. 1996). Occasionally, we located female kittens with their mother in May after the mother had given birth again; one female yearling gave birth to a litter within 800 m of its mother's nest site in 1990. Lynx kittens sometimes stayed together after separating from their mother, though we do not know how long this behaviour persisted. The earliest recorded dispersal of a male kit was on 18 March 1991. The earliest female kit dispersal was on 6 April 1992.

Female offspring often remained in or near their mother's home range (Slough, unpublished data), and we located mothers and their female offspring together regularly during this study even when both females were much older and had kittens. Two family groups, totalling 13 individuals, were observed together on a pond in our study area in late winter 1990 (D. Dennison, Pilot, personal communication). While other encounters between same- and opposite-sex Canada lynx were common, we did not observe mothers and their male kittens together.

Predatory Behaviour

We looked for hare kill sites during the winters of 1990-1991 and 1991-1992. We found the remains of 10 hares killed by lynx. Lynx never ate the gastrointestinal tract, and rarely the feet or skin. Lynx left the rear legs and sometimes the face of six hares in 1990-1991 when numbers of hares were just beginning to decline. Two hare kills were found the following winter, when hares were much less abundant, and only the gastro-intestinal tract, feet and fur were left.

In December 1990, we observed two occasions where family groups made multiple hare kills within a 50 m diameter. We don't know whether the hares were flushed and killed simultaneously, or if the second and third hares were killed opportunistically by the feeding or resting family. The hares may have been killed from a bed since lynx often bedded down in protected areas near kill sites. Family groups fanned out when hunting, and individuals were often spaced out by about 10 m, although individual kittens sometimes followed in the tracks of their mother or sibling. Groups reunited when a kill was made.

Unusual lynx behaviour was the subject of numerous reports during the winter of 1992-1993, when hares were very scarce and lynx natural mortality and dispersal peaked (Slough and Mowat 1996),

especially in February-March. There were several cases of lynx stalking domestic animals including chickens, a goat, and dogs, throughout Yukon. Two of these lynx were killed by Department of Renewable Resources staff as a control measure. They were apparently in a state of starvation: one female weighed 5.3 kg (skinned) and a male was 5.7 kg (intact carcass). An adult lynx that was found dead weighed 5.1 kg. The average weight of adult lynx was 10.3 kg for females, and 11.7 kg for males (Slough and Mowat 1996).

Vocalizations

We heard lynx make three different vocalizations. Both female and male lynx made long wailing calls during the mating period (March-April) presumably to attract and locate one another. An injured female lynx, in captivity from 7 to 27 February 1991, wailed throughout the night during the latter half of her captivity. On two occasions we saw fresh adult lynx tracks around her cage in the morning. Some captured male lynx were very lethargic before being anaesthetized and made a similar wailing call in the traps during the breeding season. On one occasion a single kitten made a wailing call before we located it, which helped us to find the nestsite.

The second call lynx made was a warning growl. Adults often made this call when captured. Young kittens also made loud high-pitched growls when we handled them. This often excited the mother who circled us calling repeatedly with a very low drawn out wail, similar to the mating call. Thirdly, lynx in family groups often made a short bark, presumably to locate one another. We saw and heard female lynx and kittens make this call throughout the winter, though it was heard more frequently in late winter. On one occasion we observed a kitten lynx walk very slowly past by us when we were cutting firewood in late winter. We heard a series of short barks in front of it and the kitten responded immediately by trotting directly towards the call. On another occasion we saw two kittens respond to a call, made presumably by the mother, by calling back themselves. Sometimes all the lynx in the group would respond to the mother's call. Barking calls were made in bouts of 5-10 calls.

Discussion

The reproductive output of lynx fluctuates widely with changes in abundance of their main prey species, Snowshoe Hares (Brand and Keith 1979; Poole 1994; Mowat et al. 1996; Slough and Mowat 1996). However, many of the details concerning the demographic changes associated with these changes in reproductive output are unknown. Felids typically have small litter sizes; domestic cats are the only other felid known to produce large litters (Rosenstein and Berman 1973; Eisenberg 1981; Deag et al. 1988). The largest litter size we observed

in the field was seven; this occurred twice in 1990 and once in 1991 (Slough and Mowat 1996). Evidence presented here suggests that litters of eight may occur occasionally as well.

When hare numbers are high, both yearling and adult females have litters up to six weeks later than the mean birth date. A yearling female from our study area had kittens weighing 264 g on 1 July 1990, indicating a parturition date of 25 June, 4 weeks later than average (Mowat et al. 1996). Another two-year-old female whose litter we did not capture was estimated to have given birth in early July.

Pregnancy rate and litter size decline more slowly than kitten survival in declining lynx populations (Brand and Keith 1979; Parker et al. 1983; Poole 1994; Mowat et al. 1996), indicating that more lynx lose their litters during the hare decline than fail to conceive. However, Poole's (1994) data suggest that few females gave birth during the first year of lynx recruitment failure in the Northwest Territories. Neither Brand and Keith (1979) nor Parker et al. (1983) could distinguish in utero from early post-partum losses, although Brand and Keith (1979) suggest early post-partum loss was most likely. Post-partum loss may be common when lynx populations are declining. Placental scar data confirms that a portion of the adult female cohort breed during hare lows (Brand and Keith 1979; Slough and Mowat 1996).

We have shown that adult lynx breed during low hare years, and that both adults and yearlings can breed late and produce young during high hare years, and that lynx have abnormally large litters for a felid. These strategies allow flexibility in reproductive output and therefore investment. Flexibility in litter size and age of first breeding allow lynx populations a strong numeric response to an increase in prey abundance. The fact that adult lynx conceive during the hare low allows pregnant female lynx the flexibility to forestall aborting or abandoning a litter until the latest possible date. This may allow individual females to take advantage of local pockets of abundant hares by reproducing during the decline/low phase of the hare cycle. Ward and Krebs (1985) showed that lynx search out areas with more abundant hares during hare population declines in another study in southwest Yukon. Macphersén (1969) demonstrated that Arctic Foxes (*Alopex lagopus*), which prey primarily on cyclic lemming populations (*Lemmus sibiricus* and *Dicrostonyx groenlandicus*), also show large numerical fluctuations.

The absence of fighting injuries, other than a rare torn ear or broken canine on captured lynx, suggested that lynx-lynx encounters were either non-aggressive or highly ritualized as suggested by Poole (1995) for lynx and by Hornocker and Bailey (1981) for Cougar (*Felis concolor*), Bobcat (*Lynx rufus*) and Leopard (*Panthera pardus*). The exception to this was during the lynx crash in 1992-1993, when two

cases of cannibalism were noted. O'Donoghue et al. (1995) reported several instances of lynx cannibalism during years of food shortage, all apparently motivated by the need for food.

Saunders (1963) in Newfoundland, Brand et al. (1976) in Alberta, and Parker et al. (1983) in Cape Breton Island found similar family group behaviour during their research to our observations in Yukon. Lindemann (1955) found family groups of European Lynx (*Lynx lynx*) remained together for 10 months, while those of the smaller European Wildcats (*Felis sylvestris*) separated after five months. Wassemer et al. (1988) found that Bobcat kittens stayed with their mother for an average of nine months, though some kittens remained with the mother until she had her next litter. Bailey (1979) found young Bobcats stayed with their mother up to one year, and he suggested males dispersed before females (Bailey 1981), which may be true in lynx as well. Ross and Jalkotzy (1992) observed sibling Cougars together after independence. Aldama and Delibes (1991) observed an adult female Spanish Lynx (*F. pardina*) sharing a Roe Deer (*Dama dama*) kill with a 6-month-old male kitten and yearling female kitten. They saw the same animals feeding on another kill a year later when the female offspring had established a home range adjacent to that of her mother's.

The bond between females and their female offspring appears to persist in lynx, as in lions (Bertram 1975) and perhaps Cheetahs and other cats (Kleiman and Eisenberg 1973). This is supported by our observations of female kittens staying on their mothers' home range and visiting their mother during their adult life. Conversely, Hornocker and Bailey (1981) studied three felids intensively (Bobcat, Cougar, and Leopard) and found no young born in their study areas ever reproduced there. Poole (1995) observed considerable overlap between certain pairs of females throughout their residency; over three years in one case. Other females had more exclusive home ranges. Poole (1995) suggested these female lynx may have been related but this was not verified. Sundquist (1981) found that juvenile female Tigers (*Panthera tigris*) established residences on their mother's home range. Female juvenile cougars sometimes remained on their natal home range in an Alberta study (Ross and Jalkotzy 1992). Kleiman and Eisenberg (1973) suggested the social structure of lions is based on matrilineal bonds. Matrilineal bonds may persist and affect social organization in lynx and other apparently non-social felids as well (Eisenberg 1981).

Keith (1990) felt that the proportion of hares vulnerable to predation may be greatest when hares are beginning to decline. This may explain why lynx left parts of their kills in 1990-1991, when hares were beginning to decline. Parker et al. (1983) reported that "remains of kills varied from only skin, viscera, and paws to nearly intact carcasses", and they felt

the extent of use was related to the time between kills rather than prey abundance. Our observations of family group hunting behaviour concur with those of Parker et al. (1983).

In addition to anecdotal reports of lynx attacking pets and livestock during hare lows, there were also several reports of lynx killing larger prey such as Red Fox (*Vulpes vulpes*; $n=2$, our study area) and Dall Sheep (*Ovis dalli*; $n=1$, Kluane area), and feeding on Moose (*Alces alces*) carrion ($n=2$, Liard and Aishihik areas; O'Donoghue et al. 1995). Lynx also fed on Moose in 1988 in the Kluane valley of southwest Yukon when hare numbers were low (D. Murray, personal communication). Stephenson et al. (1991) reported lynx more commonly killed foxes, sheep and Caribou (*Rangifer tarandus*) during low hare years. Lynx emigrated to areas where they were not normally found in abundance such as the Pacific coast of southeast Alaska during winter 1992-1993. Starvation and dispersal are characteristic of declining lynx populations (Brand and Keith 1979; Mech 1980; Parker et al. 1983; Poole 1994; Slough and Mowat 1996) and were also noted by Bailey (1974) and Knick (1990) in Bobcats when their main prey, Black-tailed Jackrabbits (*Lepus californicus*), declined dramatically. Both events may be more common in late winter.

Solitary carnivores tend to have fewer vocalizations than more social species (Ewer 1973; Estes 1991). Estes (1991: 353) reported that most small felids have six calls, four of which are hostile; i.e., hissing, spitting, growling, and screaming. He cites only purring and meowing as non-aggressive calls. We did not hear lynx purr or meow, and we had several animals in captivity for up to three weeks. However, J. Weaver (Biologist, personal communication) heard his captive lynx purr when it was young. In lynx, the meow to call mates may be replaced by the wail. Lynx appear to have a limited vocal repertoire, typical of less social felids. These calls exhibit aggression or summon conspecifics. Unlike other solitary carnivores; e.g., the weasel (*Mustela rixosa*); the lynx has distinctly different vocalizations for calling mates and young (Ewer 1973: 235).

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Age Distribution of Ramets of a Forest Herb, Wild Sarsaparilla, *Aralia nudicaulis* (Araliaceae)

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We measured ages of *Aralia nudicaulis* (Wild Sarsaparilla) ramets and site variables in a northern hardwood forest to determine how their age distributions might be affected by local environment and forest canopy disturbances. We measured ages in ten populations and at random points on two 600 m transects. Age distributions at ten sites ranged from negative exponential to uniform. Sites with many young ramets were moist and had high light intensities, conditions that may promote the establishment of new clones and recruitment of new ramets. Sites with many older ramets were dry and had low light intensities, and thus probably have fewer resources with which clones could initiate ramets. The forest-wide age distribution was a negative exponential distribution and represented a composite of different sites each of which reflected local environmental conditions and disturbance histories. Ramet recruitment may increase following any forest canopy disturbance with the greatest response after logging and the smallest after gypsy moth outbreaks.

Key Words: Araliaceae, Wild Sarsaparilla, *Aralia nudicaulis*, age distributions, recruitment, canopy disturbance, Maine.

The demography of temperate forest herbs is affected by competition, tree species composition, forest age, soil moisture, light, and type of disturbance (Cook 1996). These factors are usually studied for a few years, too short a period to understand long-term responses of herbs (Barkham 1980; Bierzychudek 1982). Instead, most long-term studies of plant populations in temperate forests have concentrated on trees using a record of their annual rings because: (1) the number of annual growth rings indicate age and variation in annual recruitment (Fritts 1976); (2) their longevity makes it possible to sample long time series (Whipple and Dix 1979); and (3) they dominate forest ecosystems and are good indicators of the timing of disturbances. However, herbs are important components of forest ecosystems and their responses to disturbance are also of interest.

Scars caused by leaf senescence in long-lived herbs also indicate age (Harper 1977) and timing of disturbances such as prairie fire (Kerster 1968) but have not been used to study forest herb populations. Like trees, a single-year study using age characteristics to measure age distributions could reveal much about the long-term population dynamics of forest herbs. Therefore, we measured ages of Wild Sarsaparilla, *Aralia nudicaulis*, ramets and site variables to determine how local environment and past canopy disturbances might (1) affect current age distributions and (2) account for variation in recruitment.

We selected *A. nudicaulis* for this study because its widespread distribution and commonness in understory of eastern forests (Fernald 1950) make it

a good indicator species. Also, its life history makes it well suited for this kind of retrospective study. Its ramets can be aged by annual leaf scars (Figure 1) (Lock 1982 in Bawa et al. 1982), are long-lived, living up to 45 years (Flanagan and Bain 1988), and are physiologically independent (Flanagan and Moser 1985), thus are effectively individuals.

Methods

Study Area and Methods

The study was conducted in the eastern half Holt Research Forest, Arrowsic, Maine (43°52'N, 69°46'W). This area was deforested heavily by the 19th century and has been naturally regenerating subsequently with some light logging (L. Moore, personal communication). A gypsy moth (*Lymantria dispar*) outbreak occurred from 1980 to 1983 (R. Bradbury, Maine Forest Service, personal communication). *Aralia nudicaulis* was untouched because gypsy moths do not commonly eat it (Mosher 1915). In the winter of 1987–1988, 10 one-ha plots were randomly selected and partly logged. *Quercus rubra* and *Pinus strobus* were dominant trees on xeric sites, *Acer rubrum*, *Q. rubra*, and *P. strobus* on mesic sites, and *A. rubrum*, *Abies balsamea*, and *Picea rubens* on moist sites. Nomenclature follows Fernald (1950).

We conducted two ramet surveys, one in August 1988 at ten sites and a second in July 1989 along four 600 m transects. In the first survey, we selected ten sites for intensive sampling to determine the relationship between age distribution and environmental

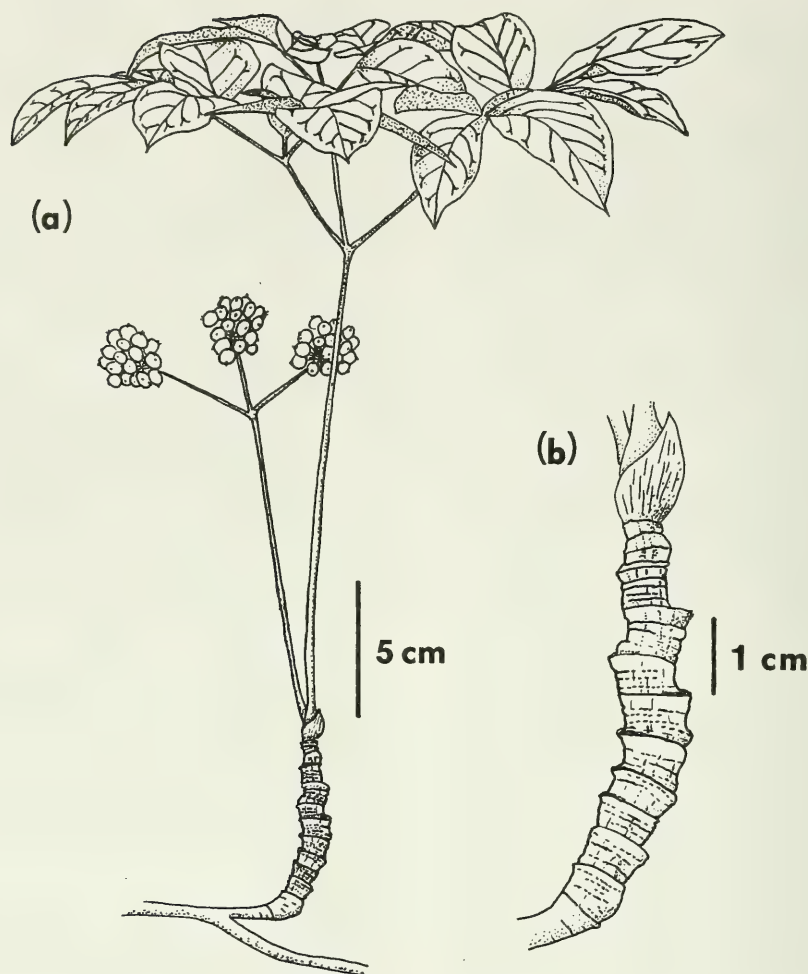


FIGURE 1. a. Fruiting ramet of *Aralia nudicaulis*; b. enlarged rhizome, with the 1 cm scale indicating two years of growth.

factors. These sites were selected because they represented populations with a range of age distributions. Sites were more than 100 apart in a 2 km² area. At each site, we surveyed ramets along four transects that diverged at random bearings from the population center. Each transect ended when no more ramets were encountered or ramet density reached < 16 ramets/ha. Ramets within these bounds were considered a population. Along each transect, we noted the ages of ramets closest to 24 random points and of their nearest neighbor. The ages of each ramet and its neighbor were not correlated at eight sites so all ramets were used to determine age distributions.

For each population, we estimated percent cover of each tree species, percent cover of conifers, total percent canopy cover, DBH of the 10 trees > 10 cm DBH closest to the population center, percent cover of rock (none, < 1%, 1- < 5%, or > 5% cover), and canopy

loss from gypsy moth infestation in the early 1980s. Percent cover was estimated by eye. Canopy loss was estimated based on a survey by cover type in 1981 (F. B. Knight, personal communication) and on amount of dead limbs on *Quercus rubra* at each site in 1988. In July 1989, we measured soil moisture (8 point scale) at a depth of 15 cm and light (lux) at a height of 30 cm at three random points on each transect of each population using an AMI Medical Technologies light and soil moisture meter. Soil moisture was measured in July when it might be limiting.

In the second survey, we sampled ramets on four 600 m transects to obtain a representative sample for the area. The transects crossed non-logged and logged areas. Along each transect, we aged ramets closest to random points within each 10 m interval and noted their location (e.g., logging gap from the 1987-1988 logging, natural gap, or intact forest).

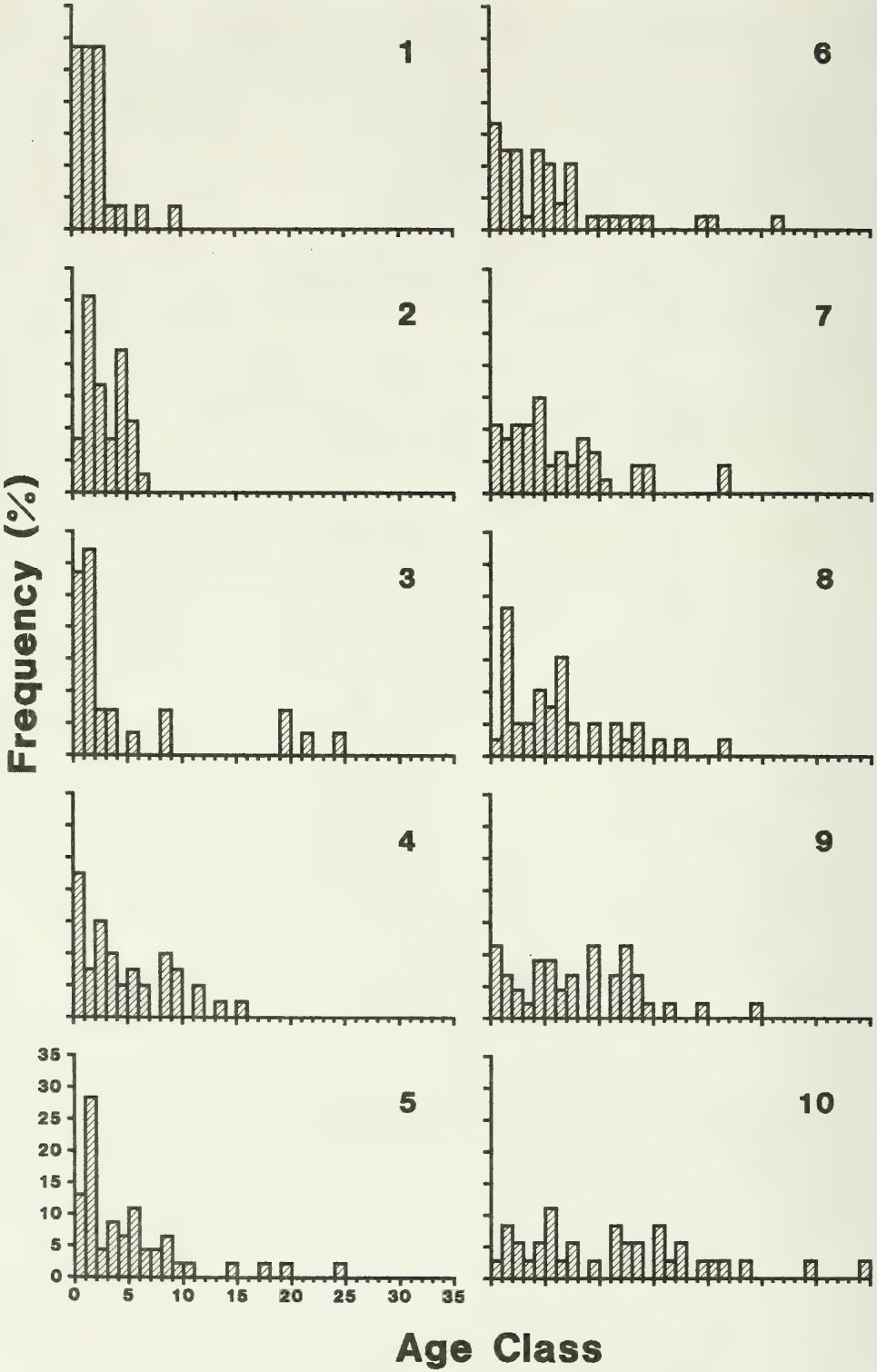


FIGURE 2. Age distributions of *Aralia nudicaulis* ramets in ten populations, 1988. The population number corresponds to the population number in Table 1.

TABLE 2. Results of the CCA between the age distributions of ten different populations and forest stand variables, including the eigenvalues of the first three CCA axes and the correlations of the first three axes with forest stand variables.

	canonical axis		
	1	2	3
eigenvalues	0.592 ¹	0.108	0.092
percent of variance accounted for by axis	73.2	13.3	11.4
correlations between forest stand variables and CCA axes			
soil moisture	0.017 ²	0.415	-0.715
light	0.533 ²	0.453	0.131
% oak cover	0.208 ²	-0.019	0.465
ledge class	-0.009	-0.131	0.454
x stem basal area	0.454	0.206	-0.268
defoliation class	0.341 ²	-0.637	-0.002

¹ the probability that this eigenvalue = 0 is 0.025.

² the t value of the canonical coefficient > 2.1.

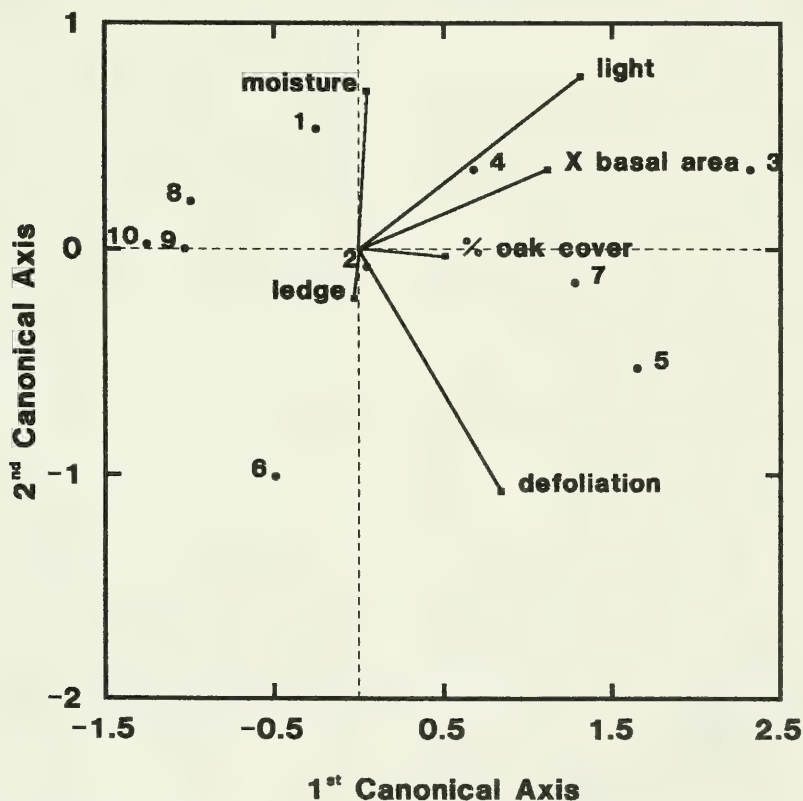


FIGURE 3. CCA ordination diagram of forest stand variables and age distributions of *Aralia nudicaulis* ramets on ten populations. The location of populations in forest stand space is indicated by filled circles and population numbers. The relationships between forest stand variables and the two axes are indicated by the direction and length of vectors emanating from the origin. For example, percent oak cover in the canopy is correlated to the first CCA axis, while soil moisture is more strongly correlated to its principal axis, the second CCA axis. Populations 1 to 4 are dominated by young ramets; populations 5 to 7 have many older ramets; and populations 8 to 10 have equal numbers of young and old ramets.

15 years old, respectively) than population 1 and 2. Other intermediate-aged populations (5, 6, and 7) occurred at sites that were drier and/or darker (Figure 3) and had age distributions with fewer young ramets compared to younger populations. Their age distributions were negative exponential.

Populations 8, 9, and 10 had uniform age distributions (Figure 2) and had older median ramet ages than other populations (Table 1). They were in sites with less light and low percent *Quercus rubra* cover because conifers were dominant (Figure 3).

In the second survey, most ramets from intact forest were in younger age classes (Figure 4). The oldest ramet was 25 years old. The best fitting age frequency distribution function was negative exponential (Figure 4) (least-squares linear regression, $r = 0.762$, $F = 28.82$, $P = 0.0005$). The total age distributions of ramets from both surveys were different ($P = 0.009$) but they were both negative exponential. The slope of the age distribution curve (Figure 4) indicated an annual ramet mortality rate of 23 %.

Canopy Disturbance

In the second survey, more ramets from logging gaps were in young age classes than ramets from natural gaps (Smirnov test, $T = 0.360$, $P < 0.05$) or from intact forest (Smirnov test, $T = 0.396$, $P < 0.0005$) (Figure 4). Logging gaps had many more ramets in the 1989 age class than in the 1987 and 1988 age classes (χ^2 test, $\chi^2 = 58.56$, d.f. = 2, $P < 0.001$), whereas intact forest had similar numbers of ramets in all three age classes (χ^2 test,

$\chi^2 = 1.11$, d.f. = 2, $P > 0.50$) (Figure 4). In short, the age distribution after logging apparently changed the greatest in the second growing season (1989) following the disturbance (winter of 1987-1988). Although natural gaps had more ramets in younger age classes than intact forest (Figure 4), their age distributions were not different (Smirnov test, $T = 0.124$, $P > 0.10$). The recruitment index peaked one year after defoliation (Figure 5).

Discussion

Environmental Factors

Ramet age distributions were influenced by environmental factors. Clones on moist, open sites were rapidly growing, producing many new ramets (Flanagan and Bain 1988) and so their populations were largely comprised of young ramets. *Aralia nudicaulis* is most abundant on these sites especially if the site is dominated by deciduous trees (Flanagan and Bain 1988; Ohman and Grigal 1979; Roberts and Gilliam 1995; Zavitkouski 1976). Clones on moderately dry and/or dark sites have fewer resources available to them for growth and so their populations were comprised of both young and old ramets. They expand slowly and hence were comprised mostly of older ramets (Flanagan and Bain 1988). Their recruitment of ramets was not affected by the gypsy moth outbreak perhaps because the conifer canopy was not defoliated. Thus, ramet recruitment increases as one moves from dry, dark forest sites to moist, open forest sites.

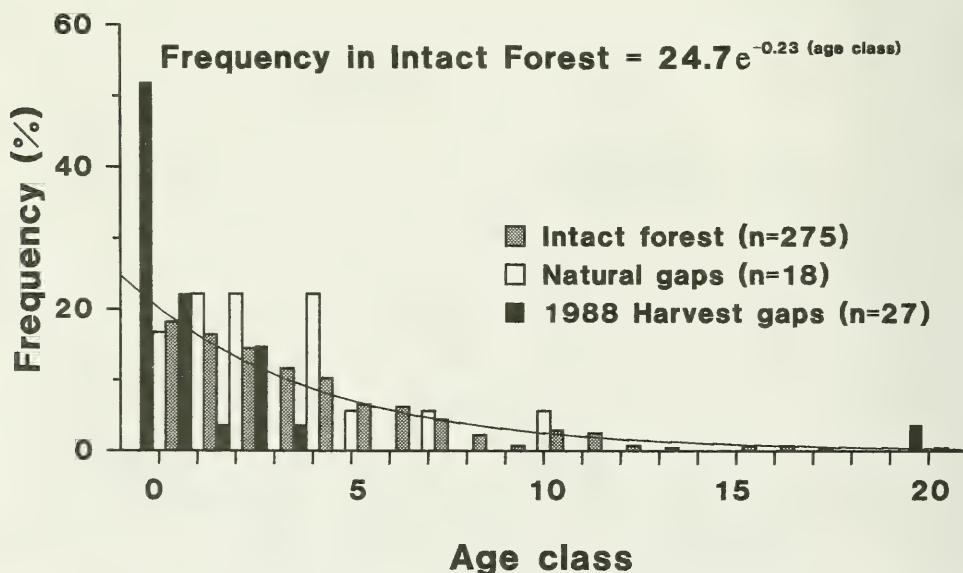


FIGURE 4. Age distribution of *Aralia nudicaulis* ramets on transects from intact forest, natural gaps, and logged gaps, 1989. Fitted line indicates a negative exponential relationship between frequency and age class for ramets in intact forest. The equation is for the fitted line and describes the relationship.

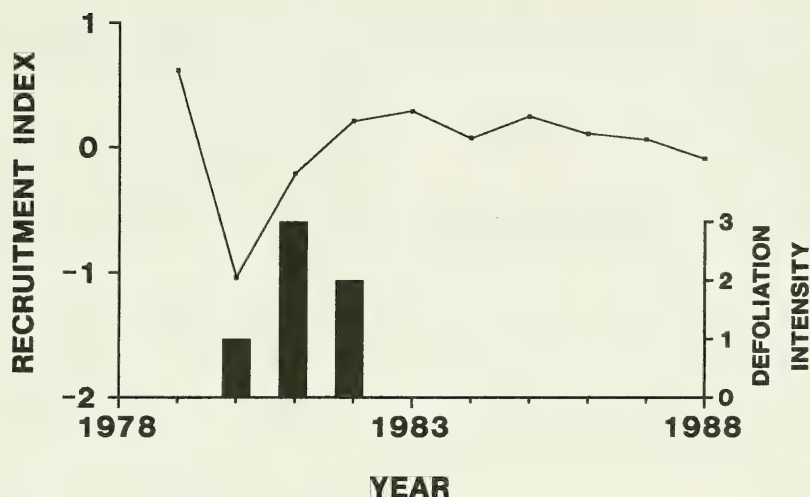


FIGURE 5. Annual recruitment index of *Aralia nudicaulis* ramets (solid line) and defoliation intensity in 1980, 1981, and 1982 (filled bars). The index is calculated from the age distribution and is more fully explained in the text.

Environmental variation affects the age structure of ramets of other clonal understory species. *Maianthemum canadense* populations with many young ramets occurred in mixed mesic forest stands, while populations with mostly older ramets occurred in more stressful forest stands with a conifer overstory or water-logged soils (Silva et al. 1982). Dense canopy has also been shown to reduce recruitment of other understory clonal species (e.g., Tappeiner et al. 1991, Tappeiner and Alback 1989).

The forest-wide age distribution was negative-exponential which suggests that ramet mortality was constant across age classes and mortality equals recruitment (e.g., Good and Good 1972). This could only be verified by following individuals through time (Hett 1971). Estimated annual mortality, 23%, was much higher than that of large individuals (4%) monitored from 1987-1991 (A. Whitman, unpublished data). However, the latter mortality estimate was biased because larger individuals might have lower annual mortality. Also, a 23% annual mortality is comparable to the similarly estimated mean mortality rate for ten northern forest shrub species: 20.2% (Balogh and Grigal 1987).

Canopy Disturbance

The proportion of ramets in young age classes varied among the different disturbance types. There was little difference in age distributions between natural gaps and intact forest perhaps because the sample of ramets from natural gaps was too small ($n=18$) to detect the small effect that natural gaps have on forest herbs (Collins and Pickett 1987). In contrast, logging appeared to have a greater on ramet recruit-

ment, although the response was not apparent until the second growing season after the logging. Apparently, clones of *Aralia nudicaulis* take one year to acquire resources to permit growth and production of new ramets in response to increases in light. In Minnesota, the response of *A. nudicaulis* and other understory vegetation to winter logging was not observed until one growing season later (Outcalt and White 1981). Large disturbances such as those created by logging increase recruitment of *A. nudicaulis* (Bartell 1983) and other herbs (Tappeiner and Alback 1989) and skew age distributions toward younger age classes in understory shrubs (Tappeiner et al. 1991; Luken 1988). The gypsy moth outbreak in the early 1980s may also have influenced age distributions and recruitment. The recruitment index showed a one-year lagged response similar to that after logging. Although increases in sapling growth have been observed after gypsy moth outbreaks (Collins 1961), increases in plant recruitment have not.

For these three disturbance types, logging, natural treefalls, and insect outbreaks, light was probably the primary factor that increased ramet recruitment because nitrogen and moisture levels are not greater in gaps than the surrounding forest in northern hardwood forests (Collins and Pickett 1987). If so, ramet recruitment may have been greater in logging gaps than in natural gaps because logging gaps were much larger than natural gaps (median values: 113 versus 21 m², J. Rudnick, unpublished data) and therefore had more light (Collins and Pickett 1987). Although light increases after canopy defoliation by gypsy moths (Mattson and Addy 1975), this increase may

shorter in duration and lower in intensity than occurs with canopy gaps. Thus, the small and large canopy disturbances can affect short-term recruitment and long-term age distribution of ramets of *Aralia nudicaulis* and influence their population dynamics in the forest understory for several years after the event.

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Archaeological Records of the Extinct Sea Mink, *Mustela macrodon* (Carnivora: Mustelidae), from Canada

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The extinct Sea Mink, *Mustela macrodon*, is reported from bones found in prehistoric archaeological sites in southern New Brunswick. The former range of this species, based on historical records and archaeological remains, is considered to have included coastal Maine, coastal New England as far south as Massachusetts, the southern coasts of the Maritime Provinces, and possibly Newfoundland. The association of some Sea Mink bones reported here with flaked lithic materials from geological sources in Maine suggests the bones were brought to New Brunswick by Native people, rather than representing a population of Sea Mink living on the New Brunswick coast in the past.

Key Words: Sea Mink, *Mustela macrodon*, Quoddy region, Weir site, New Brunswick, Late Woodland period, Native exchange systems.

Prentiss (1903) based the first description of the Sea Mink, *Mustela macrodon*, on bones from an archaeological site at Brooklin, Maine, and archaeological remains continue to be the main source of information about this enigmatic and controversial species (see Figure 1 for locations of places referred to in the text). A. E. Spiess (1996: personal communication) and colleagues are currently preparing a detailed analysis of the species based on bones from sites in Maine. As Youngman (1989) pointed out in response to Campbell (1988), a decade ago there were no verified Canadian records of the Sea Mink. Here we report the first Sea Mink bones found at Canadian archaeological sites and consider their implications.

The Sea Mink bones reported here, from the Weir site (BgDq6), were collected during an archaeological project (Black 1987, 1992) studying the prehistoric and historic human ecology of the Quoddy region. Black recovered the bones during excavations in 1993. Reading analyzed the faunal remains from these excavations under Savage's supervision; Savage and Reading identified the bones as those of *Mustela macrodon* in 1994 (Illingworth-Cooper 1994; Reading 1994*). In addition, we refer to the only other Sea Mink bone reported from a Canadian archaeological site: a calcined fragment of a left mandible recovered from the Mud Lake Stream site (BkDw5) by M. Deal (1985: 50), and identified by A. E. Spiess as *M. macrodon* in 1990 (Deal, Morton and Foulkes 1991: 183).

The Sea Mink

The Sea Mink has been reported as having become extinct as long ago as 1860 (Hardy 1903) and as recently as 1920 (Dilworth 1984: 182). A mink reported to have been caught on Campobello Island, New Brunswick, in 1894 (Wright 1962) and preserved as a mounted specimen (Norton 1930), has been both accepted (Banfield 1974: 332; Campbell 1988) and rejected (Manville 1966: 7; Youngman 1989) as an example of the Sea Mink. Most mammalogists (Peterson 1966: 250; Banfield 1974: 332; Hall 1981: 1004) accept the validity of *Mustela macrodon* (Prentiss) as a distinct species. However, Squires (1968: 41) considered it was "probably only a variety of common mink [*Mustela vison*]" and Manville (1966: 10) concluded it was a subspecies of Mink, designating it *Mustela vison macrodon*.

The size of the Sea Mink has been estimated as double that of the Mink (*Mustela vison* Schreber) by Banfield (1974: 332) and 20–25% larger than the Mink by Loomis (1911: 227). The Sea Mink is known to have inhabited rocky coasts and offshore islands, but virtually nothing is known of its habits and reproductive behaviour (Banfield 1974: 332). Most Sea Mink specimens come from archaeological sites along the central and southern coasts of Maine (Prentiss 1903; Loomis 1911; Moorehead 1922; Manville 1942; Waters and Ray 1961). Although tradition and anecdotal evidence (Seton 1921: 168; Wright 1962; Squires 1968: 41; Campbell 1988) have associated the Sea Mink with the New Brunswick and Nova Scotia shores of the Bay of Fundy, and even with Newfoundland, in Maine no Sea Mink remains have been found north

*see Documents Cited between Acknowledgments and Literature Cited.

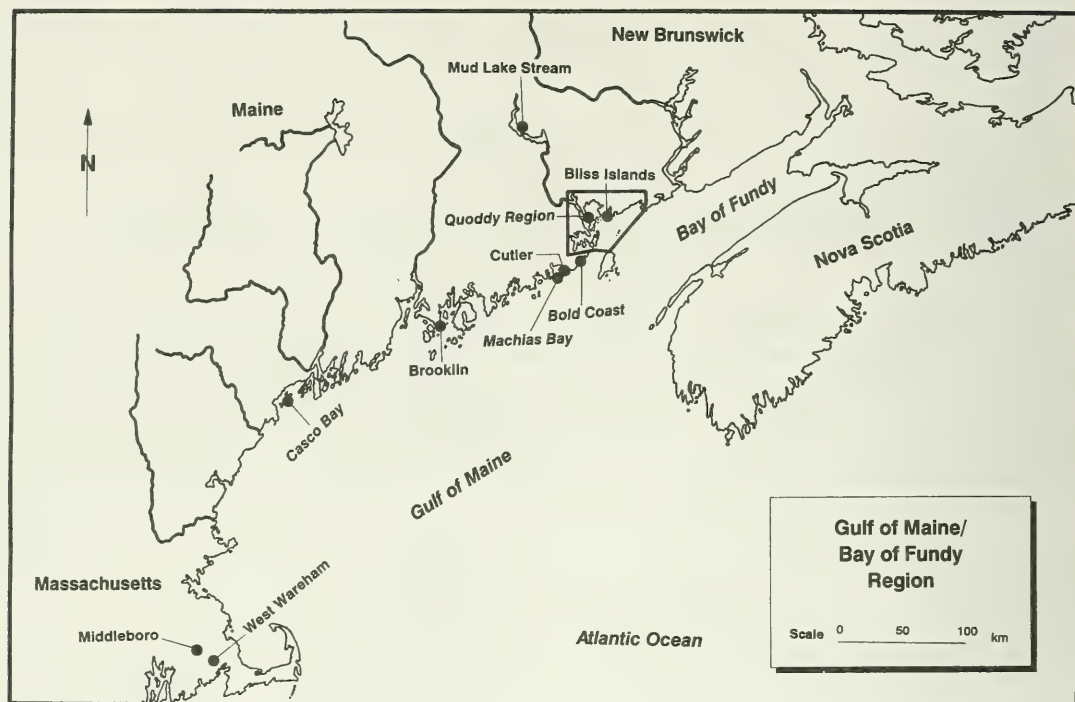


FIGURE 1. Map of the Gulf of Maine/Bay of Fundy region showing the locations of places referred to in the text.

and east of Cutler, on the eastern edge of Machias Bay (A. E. Spiess 1996: personal communication).

Archaeological evidence has been used to extend the range of the Sea Mink south to Massachusetts (Manville 1966: 3-4). A right femur and left radius were found during the excavation of the Wapanucket #6 site in Middleboro, Massachusetts, an Archaic village site radiocarbon dated to about 4300 years ago (Robbins 1959); these bones may date from as recently as the historic period to as long ago as the Late Archaic period (Waters and Ray 1961). A right ulna was recovered from a Woodland period shell midden and ceremonial site at West Wareham, Massachusetts (Waters and Mack 1962). No Sea Mink have been reported between Casco Bay, Maine, and southeastern Massachusetts (Manville 1966: 4).

Sea Mink bones from the Weir site

The Weir site is located on the Bliss Islands, 1 km offshore from Blacks Harbour, New Brunswick. Native people, presumably ancestors of the Passamaquoddy people who lived in the Quoddy region at European contact, inhabited the site periodically from about 2500 years ago to about 1000 years ago. The site, about 800 m² in area and 50-100 cm in depth, consists of a series of soil layers, gravel living floors and shell middens resting on a bedrock outcrop and covered by a 5-30 cm thick layer of peat

soil. The site is virtually undisturbed by historic activity and bone preservation is excellent because the marine shells have neutralized the natural acidity of the soil. The Sea Mink bones were found in the most recent cultural layers, radiocarbon dated at 1300 to 1000 years ago (the Late Woodland period).

The bones include a complete right mandible (with C_1 , P_2 , P_3 , P_4 and M_1 in situ), a left cranial portion (including part of the orbit), a right radius, a right 4th metatarsal, a proximal phalanx, a portion of the left fibula, a caudal vertebra, and possible portions of a femur and the first and second cervical vertebrae. These remains could be accounted for by a single Sea Mink skeleton; however, the spatial distribution, and size differences among the bones, suggest they may belong to two or more individuals. The size and robustness of the mandible, cranium and radius suggest these bones represent adult male Sea Mink. The distal end of the radius bears a transverse cut mark consistent with marks made by stone tools during skinning or dismemberment.

Unfortunately, because intact maxillae were not recovered, the most common criterion used to distinguish *M. macrodon* from *M. vison* in biological keys (Peterson 1966: 250; Hall 1981: 1004; Dilworth 1984: 182), maxillary molar-premolar tooth-row length greater than 20 mm, cannot be applied in this case. Table 1 compares the Weir site Sea Mink mandible and radius with those of 15 adult Mink cap-



FIGURE 2. The right mandible of Sea Mink (*M. macrodon*) from the Weir site compared with the right mandible of an adult male Mink (*M. vison*). Above: *M. macrodon* (BgDq6:2794-1) collections of the Department of Anthropology, University of New Brunswick. Below: *M. vison* (FA207-14); collections of the Faunal Osteo-archaeology Laboratory, Department of Anthropology, University of Toronto.

tured in southern New Brunswick from 1981 to 1983. The Sea Mink bones are 23.6% to 34.2% larger than those of male Mink and 37.3% to 54.9% larger than those of female Mink. Figure 2 shows the Weir site mandible compared to that of an adult male Mink.

Sea Mink and prehistoric exchange systems

Archaeological Sea Mink crania are typically fragmented and many mandibles and extremity bones exhibit cut marks (Loomis 1911). Native people are assumed to have trapped these animals as food, and to have used the pelts for clothing. However, it is possible they also used Sea Mink for exchange and ceremonial purposes (see, for example, Waters and Mack 1962: 430).

In both areas where Sea Mink bones were found at the Weir site, they are associated with stone tools and tool-making debris of a distinctive lithic material commonly called Kineo felsite or Kineo rhyolite, but more technically known as Kineo-Traveller Mountain porphyry (Doyle 1995: 304). This stone,

TABLE 1. Osteometric comparison of Weir site Sea Mink with Mink from southern New Brunswick.

Measurement	Mustela vison male n = 8		Mustela vison female n = 7		Weir site <i>Mustela macrodon</i> n = 1 (cm)	Weir site <i>M. macrodon</i> % larger than male <i>M. vison</i>	Weir site <i>M. macrodon</i> % larger than female <i>M. vison</i>
	range (cm)	mean (cm)	range (cm)	mean (cm)			
1 length of radius	2.87-3.11	3.00	2.49-2.97	2.63	3.71	23.78	41.18
2 width of distal radius	0.55-0.65	0.59	0.46-0.60	0.51	0.79	34.21	54.93
3 length of mandible	3.53-3.89	3.72	3.16-3.38	3.34	4.80	29.08	43.80
4 height of ascending ramus of mandible	1.58-1.82	1.70	1.36-1.60	1.46	2.24	31.42	53.48
5 length of mandibular molar-premolar tooth-row	1.83-1.99	1.90	1.66-1.82	1.72	2.36	23.65	37.29

Note: All *M. vison* specimens are curated in the collections of the Natural Sciences Division, New Brunswick Museum.

composed of a glassy, green groundmass interspersed with weathered, rectangular feldspar crystals and small round beads of clear quartz, was among the materials preferred by Native people in Maine for making flaked stone tools. It outcrops in northern central Maine in the Mount Kineo/Traveller Mountain area and is available from bedrock sources and from glacial boulder trains extending from the mountains to the central Maine coast.

It is very unlikely that Kineo-Traveller Mountain porphyry was transported glacially to the Quoddy region, and no float cobbles of this material have been identified in the region. Rather, Native people probably brought the stone to the Weir site from sources in central Maine. The Late Woodland period radiocarbon dates from the most recent layers at the Weir site reinforce this interpretation: this is a period when there is considerable archaeological evidence for exchange relationships among Native groups living in the Maine/Maritimes area (Bourque 1994: 34-35). The association of Sea Mink bones with lithic material from Maine suggests that Sea Mink were brought to the Weir site from Maine, either directly through a movement of Native people, or indirectly through person to person exchange relationships connecting Native groups. The bones may have been transported in carcasses preserved as foodstuffs, as part of Sea Mink pelts, as clothing or personal adornment items, or as ceremonial items.

That Sea Mink bones have not been identified previously in the Quoddy region, despite a long history of archaeological research and extensive excavations (Black 1992: 10-20), supports the interpretation that populations of Sea Mink were not present in the region in the past. The Bold Coast between Machias Bay and the Quoddy region, 30 km of rugged high-gradient shoreline unbroken by estuaries, may have served as a barrier limiting the northeastern distribution of the Sea Mink.

The Sea Mink bone from the Mud Lake Stream site, located in the St. Croix drainage, 100 km upstream from the Quoddy region, presents an interesting parallel to the Sea Mink bones found in Massachusetts: the Wapanucket #6 site is about 12 miles (19.2 km), and the West Wareham site about 2 miles (3.2 km) from the nearest salt water. Finds of a few Sea Mink bones on interior sites at the extremes of their distribution support the argument that these bones were transported as part of Native exchange systems, rather than resulting from Native people trapping local Sea Mink in Massachusetts and New Brunswick.

In light of the evidence from New Brunswick, it would be instructive to re-evaluate the archaeological contexts of the Sea Mink remains from Massachusetts to determine, first, if they were associated with lithic materials known to have functioned as exchange goods, and second, whether the Sea

Mink bones from the Wapanucket #6 site suggest that Sea Mink served as exchange items during the Late Archaic period, as well as during the Late Woodland period. The identifications and cultural contexts of all archaeological mink remains in the Northeast should be carefully scrutinized, since they contain the information that can be used to challenge or confirm the historical and anecdotal accounts of Sea Mink beyond coastal Maine.

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Helminths of Bullfrogs, *Rana catesbeiana*, Green Frogs, *R. clamitans*, and Leopard Frogs, *R. pipiens* in New Brunswick

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Twenty-three species of helminths were identified from Bullfrogs (*Rana catesbeiana*) (n = 268), Green Frogs (*R. clamitans*) (n = 234) and Leopard Frogs (*R. pipiens*) (n = 280) collected at seven sites in New Brunswick. Twelve species were common to the three hosts while only three were restricted to a single host. Eighteen species are newly reported from New Brunswick. Of these, six species are also new for Canada. The Bullfrog, the more aquatic of the three hosts, harboured the greatest number of helminth species overall. Most of the helminths of New Brunswick Bullfrogs, Green Frogs, and Leopard Frogs have been recorded parasitizing a variety of amphibians and are widely distributed in North America. Encysted larval *Echinostoma trivolvis* was the most widely occurring helminth in all three frogs. Digeneans with complex life-cycles dependant on aquatic intermediate hosts predominate in terms of species diversity and abundance in Bullfrogs and Green Frogs. In the more terrestrial Leopard Frog, nematodes with direct life-cycles are the most abundant and widespread adult helminths infecting this host. Cestodes are relatively uncommon and acanthocephala are rare or accidental.

Key Words: Bullfrog, *Rana catesbeiana*, Green Frog, *Rana clamitans*, Leopard Frog, *Rana pipiens*, helminths, New Brunswick.

Aho (1990) has noted that there are few comprehensive surveys of the helminths of anurans and that the parasite fauna of only a small fraction of amphibians can be regarded as well known. In Maritime Canada, Stafford (1902) reported collecting the lung fluke, *Haematoloechus longiplexus*, in New Brunswick and Nova Scotia. Simon (1922) collected the intestinal digenean, *Loxogenes arcanum*, from *R. clamitans* in Nova Scotia, and Walton (1941a) recorded the nematode *Foleyella americana* parasitic in *R. clamitans* [Green Frog] from Chatham, New Brunswick. Kennedy (1980) collected *H. longiplexus* and *H. breviplexus* from *R. catesbeiana* [Bullfrog] at Halifax, Nova Scotia. In this paper we report, in systematic order, the helminth parasites of *R. catesbeiana*, *R. clamitans* and *R. pipiens* [Leopard Frog] from seven sites in New Brunswick in 1989 and 1990.

The Green Frog and Leopard Frog are found throughout New Brunswick but are most abundant in the southern and central counties (Gorham 1970). Central New Brunswick is near the northern limit of the North American range for the Bullfrog. The Bullfrog is mainly aquatic, the Leopard Frog is largely terrestrial outside the breeding season, and the Green Frog is a species of pond margins and as such straddles the habitat of the other two species (McAlpine and Dilworth 1989).

Methods

Frogs were collected from April through September 1989 and 1990, at seven sites in southern

and central New Brunswick (Table 1), killed, and either examined for helminths fresh, or frozen, stored and necropsied later. All frog carcasses have been added to the herpetological collections of the New Brunswick Museum. Viscera were removed from frogs and examined for helminths in individual petri dishes of saline (fresh, newly-killed frogs) or distilled water (previously frozen frogs). The intestinal tract (duodenum to rectum) was divided into eight sections of equal length and the stomach and rectum were each divided into equal anterior and posterior sections. Each section was examined individually and all helminths were counted, identified, and tabulated by section. Digeneans, cestodes and nematodes were killed and fixed in hot 70% ethyl alcohol. Acanthocephalans were killed in cold, distilled water and fixed in 70% ethyl alcohol. Digeneans, cestodes and acanthocephalans were stained in Mayer's paracarmin and mounted in Canada balsam. Nematodes were cleared in glycerin or lactophenol and examined as temporary mounts. Representative series of all helminths reported have been deposited in the collections of the New Brunswick Museum. Illustrations of each species were prepared using a Leitz drawing tube and are included here following Brooks' (1976) recommendation for amphibian helminth surveys. Terminology follows that of Margolis et al. (1982). Experimental infections using new-hatched domestic chicks were used to identify echinostome metacercariae encysted in the kidneys of all three frog species. Frogs were pitied,

TABLE 1. Collection locations and sample sizes (n) for Bullfrogs (BF), Green Frogs (GF), and Leopard Frogs (LF) examined for helminths in New Brunswick in 1989 and 1990.

Location	Species		
	BF	GF	LF
Barkers Point, York County (45° 57' N, 66° 37' W)	10	23	73
Jemseg, Queens County (45° 50' N, 66° 07' W)	0	0	101
Scovil Point, Queens County (45° 46' N, 66° 08' W)	12	0	100
Darlings Island, Kings County (45° 30' N, 65° 53' W)	0	0	5
Black River, Saint John County (45° 17' N, 65° 46' W)	0	194	0
Latimer Lake, Saint John County (45° 18' N, 65° 55' W)	42	4	0
Twin Lakes, Charlotte County, (45° 14' N, 67° 05' W)	204	13	1
Totals	268	234	280

kidneys removed, and metacercariae from a single host species force-fed to newly hatched birds. Birds from each host infection were housed separately in the museum laboratory and then killed at 16 to 37 days post-infection and the intestinal tract examined for helminths.

Results

Prevalence and intensity of helminth species by site for each of the three hosts are shown in Table 2. In the systematic list that follows species newly reported for Canada (and New Brunswick) are marked with one asterisk (*), those newly reported for New Brunswick only, with two asterisks (**). The host(s) infected is followed by the site(s) of infection in the host and previously published host and geographic distributions for the helminths encountered are also updated and, where necessary, corrected.

Cestoda
Family Bothriocephalidae
Bothriocephalus sp.
(Figure 1)

R. catesbeiana, ileum, immediate post duodenum.
The single infection of two immature worms is considered accidental. Determination of species within this genus on the basis of scolex alone is difficult. In North America, *B. rarus* Thomas, 1937 is the only widespread member of the genus commonly infecting amphibians. Del Fosse and Whittaker (1971) suggest this species may be host-specific to the newt, *Notophthalmus viridescens*. Anura have not previously been recorded as hosts for *Bothriocephalus* species.

Family Nematotaeniidae
**Cylindrotaenia americana* Jewell, 1916,
(Figures 2 & 3)
R. catesbeiana, ileum, *R. clamitans*, ileum.
This cestode was common only in Green Frogs at

Black River, where one frog carried 93 worms. Although *C. americana* was present in a Green Frog collected at Twin Lakes, this cestode was not found in the large sample of Bullfrogs collected at this site.

Jones (1987) identified *C. americana* as an anuran parasite and *C. idahoensis* as a parasite of plethodontid salamanders. Although *C. americana* has been widely reported in North and South America, Czechoslovakia, Burma and Africa, the revision of Jones (1987) leaves the status of *Cylindrotaenia* reported from hosts other than anura in North and South America in need of confirmation. Dyer (1986) suggests that neotropical and North American *C. americana* may not be conspecific and McAllister (1991) reviews problems with the single African record.

Previous definitive host records are summarized in Brooks (1976), Prudhoe and Bray (1982) and McAllister (1991) with the following additions and corrections: *Desmognathus brimleyorum* in Arkansas (McAllister et al. 1995a); *Hyla avivoca* in Arkansas (McAllister et al. 1993b); *R. pipiens* in Michigan (Lawler 1939); *Plethodon albagula* in Arkansas (McAllister et al. 1993a). Walton (1941b) is the only source for this cestode in *Bufo canorus* in California, although both Douglas (1958) and McAllister (1991) cite Ingles (1936).

Family Proteocephalidae
**Proteocephalus saphena* (Osler, 1931),
Brooks, 1978
(Figure 4, 5 & 6)
R. catesbeiana, ileum, *R. clamitans*, ileum, *R. pipiens*, ileum.

Of the cestodes encountered this species was the most widespread among hosts and locations sampled. Nonetheless, it always occurred at low intensities of infection (maximum = 5) and at prevalences under 5%.

Previous definitive host records are summarized in Prudhoe and Bray (1982).

TABLE 2. Prevalence and intensity of helminths recorded from Bullfrogs (BF), Green Frogs (GF), and Leopard Frogs (LF) at seven sites in New Brunswick in 1989 and 1990. Worms present as larval stages indicated by (L), otherwise adults. *Alaria* and *Echinostoma* were recorded as present or absent only.

Parasite & collection site	Host	N	Prev. (%)	Intensity		range	n
				\bar{x}	\pm SE		
Cestoda							
<i>Bothriocephalus</i> sp.							
Twin Lake	BF	204	0.5	2.0			1
<i>Cylindrotaenia americana</i>							
Latimer Lake	BF	42	4.8	1.0			2
Black River	GF	194	7.2	9.9	24.1	1-93	14
Twin Lakes	GF	13	7.7	1.0			1
<i>Proteocephalus saphena</i>							
Latimer Lake	BF	42	2.4	1.0			1
Twin Lakes	BF	204	0.5	3.0			1
Barkers Point	GF	23	13.0	3.0	2.0	1-5	3
Barkers Point	LF	73	5.5	2.0	0.8	1-3	4
Jemseg	LF	101	1.0	1.0			1
Scovil Point	LF	100	3.0	2.7	2.1	1-5	3
Proteocephalan sp. (L)							
Barkers Point	BF	10					1
Barkers Point	GF	23	4.3	3.0		3	1
Barkers Point	LF	73	1.4	1.0			1
Jemseg	LF	101	1.0	5.0			1
Scovil Point	LF	100	4.0	1.8	1.5	1-4	4
Digenea							
<i>Halipegus occidualis</i>							
Barker's Point	BF	10	10.0	7.0			1
Latimer Lake	BF	42	2.4	1.0			1
Scovil Point	BF	12	16.6	1.5	0.7	1-2	2
Twin Lakes	BF	204	11.8	2.4	3.0	1-15	24
Barkers Point	GF	23	8.7	2.0	0.0	2	2
Jemseg	LF	101	2.0	2.0	1.4	1-3	2
<i>Apharyngostrigea pipientis</i> (L)							
Latimer Lake	BF	42	2.4	12.0			1
Scovil Point	BF	12	8.3	14.0			1
Twin Lakes	BF	204	2.0	14.8	26.8	1-55	4
Barkers Point	GF	23	17.4	9.5	7.0	1-18	4
Black River	GF	194	0.5	1.0			1
Barkers Point	LF	73	12.3	10.2	16.3	1-51	9
Darling's Island	LF	5	20.0	97.0			1
Jemseg	LF	101	14.9	9.7	12.8	2-46	15
Scovil Point	LF	100	44.0	22.2	43.3	1-215	44
<i>Alaria arisaemoides</i> (L)							
Barkers Point	BF	10	20.0				
Scovil Point	BF	12	8.3				
Barkers Point	GF	23	4.5				
Barkers Point	LF	73	2.8				
Jemseg	LF	101	14.9				
Scovil Point	LF	100	35.0				
<i>Echinostoma trivolvis</i> (L)							
Barkers Point	BF	10	80.0				
Latimer Lake	BF	42	40.5				
Scovil Point	BF	12	83.3				
Twin Lakes	BF	204	98.0				
Barkers Point	GF	23	87.0				
Black River	GF	194	1.5				
Latimer Lake	GF	4	50.0				
Twin Lake	GF	13	84.6				

continued

TABLE 2. (Continued)

Parasite & collection site	Host	N	Prev. (%)	Intensity		range	n
				\bar{x}	\pm SE		
<i>Echinostoma trivolvis</i> (L) continued							
Barkers Point	GF	23	8.7	2.0	0.0	2	2
Barkers Point	LF	73	47.9				
Darlings Island	LF	5	100.0				
Jemseg	LF	101	45.5				
Scovil Point	LF	100	82.0				
Twin Lakes	LF	1	100.0				
<i>Megalodiscus temperatus</i>							
Twin Lakes	BF	204	9.3	3.9	3.9	1–14	19
Twin Lakes	GF	13	7.7	1.0			1
<i>Haematoloechus longiplexus</i>							
Barkers Point	BF	10	50.0	26.8	30.4	3–79	5
Latimer Lake	BF	42	14.3	1.3	0.8	1–3	6
Scovil Point	BF	12	8.3	10.0			1
Twin Lakes	BF	204	2.5	3.0	2.9	1–8	5
Barkers Point	GF	23	17.4	2.5	1.3	1–4	4
Black River	GF	194	1.5	1.7	1.2	1–3	3
<i>Haematoloechus medioplexus</i>							
Barkers Point	LF	7.3	12.3	9.2	12.5	1–41	9
Jemseg	LF	101	12.9	8.6	11.3	1–45	13
Scovil Point	LF	100	15.0	8.1	11.1	1–34	15
<i>Haematoloechus varioplexus</i>							
Barkers Point	BF	10	20.0	2.5	0.7	2–3	2
Twin Lakes	BF	204	13.3	2.5	3.0	1–14	28
Barkers Point	GF	23	21.7	13.0	14.8	2–37	5
Barkers Point	LF	73	1.4	1.0			1
Scovil Point	LF	100	1.0	4.0			1
<i>Glypthelmins quieta</i>							
Latimer Lake	BF	42	2.4	1.0			1
Scovil Point	BF	12	25.0	1.0	0.0	1	3
Twin Lakes	BF	204	11.8	3.3	4.5	1–22	24
Barkers Point	GF	23	65.2	99.2	196.5	3–773	15
Black River	GF	194	0.5	1.0			1
Twin Lakes	GF	13	23.1	2.7	2.1	1–5	3
Barkers Point	LF	73	4.1	1.3	0.6	1–2	3
Darlings Island	LF	5	60.0	1.7	0.6	1–2	3
Scovil Point	LF	100	8.0	3.1	2.6	1–8	8
<i>Loxogenes arcanum</i>							
Latimer Lake	BF	42	7.1	11.3	10.4	3–23	3
Scovil Point	BF	12	8.3	4.0			1
Twin Lakes	BF	204	18.6	70.2	63.3	2–194	38
Barkers Point	GF	23	4.3	9.0			1
<i>Gorgoderina attenuata</i>							
Barkers Point	BF	10	10.0	5.0			1
Latimer Lake	BF	42	28.6	1.3	0.5	1–2	12
Twin Lakes	BF	204	2.5	7.8	12.5	1–30	5
Barkers Point	GF	23	8.6	6.6	7.8	1–12	2
Black River	GF	194	11.3	2.3	2.5	1–11	22
Twin Lakes	GF	13	15.4	8.5	10.6	1–16	2
Barkers Point	LF	73	2.7	1.0	0.0	1	2
Jemseg	LF	101	22.8	3.0	3.3	1–16	23
Scovil Point	LF	100	32.0	5.9	11.1	1–50	32
<i>Gorgoderina simplex</i>							
Barkers Point	BF	10	50.0	5.4	5.9	1–15	5
Latimer Lake	BF	42	2.4	1.0			1
Scovil Point	BF	12	75.0	8.6	13.1	1–39	9

continued

TABLE 2. (Continued)

Parasite & collection site	Host	N	Prev. (%)	Intensity		range	n
				\bar{x}	\pm SE		
<i>Gorgoderina simplex</i> continued							
Twin Lakes	BF	204	39.7	3.0	2.9	1–20	81
Barkers Point	GF	23	30.4	2.9	3.3	1–10	7
Jemseg	LF	101	10.0	1.8	1.0	1–4	10
Scovil Point	LF	100	2.0	1.0	0.0	1	2
Nematoda							
<i>Rhabdias ranae</i>							
Black River	GF	194	0.5	1.0			1
Barkers Point	LF	73	4.1	3.0	2.0	1–5	3
Darlings Island	LF	5	60.0	3.0	2.0	1–5	3
Jemseg	LF	101	77.2	12.4	15.9	1–91	78
Scovil Point	LF	100	46.0	7.9	15.2	1–99	46
<i>Cosmocercoides dukae</i>							
Twin Lakes	BF	204	3.9	1.6	1.2	1–4	8
Black River	GF	194	7.7	2.6	4.1	1–17	15
Barkers Point	LF	73	1.4	1.0			1
Darlings Island	LF	5	60.0	7.7	1.5	6–9	3
Jemseg	LF	101	60.4	12.7	24.1	1–160	61
Scovil Point	LF	100	4.0	5.6	5.9	1–14	4
<i>Falcaustra inglisi</i>							
Latimer Lake	BF	42	26.2	3.0	2.3	1–9	11
Twin Lakes	BF	204	2.0	1.0	0.0	1	4
Black River	GF	194	38.1	10.7	13.4	1–68	74
Latimer Lake	GF	4	25.0	1.0			1
<i>Spiroxys contortus</i> (L)							
Barkers Point	BF	10	20.0	7.0	5.7	3–11	2
Scovil Point	BF	12	41.7	12.2	9.0	1–24	5
Twin Lakes	BF	204	6.4	2.4	2.6	1–10	13
Scovil Point	LF	100	2.0	1.0	0.0	1	2
<i>Ozwardocruzia pipiens</i>							
Barkers Point	BF	10	20.0	1.5	0.7	1–2	2
Latimer Lake	BF	42	4.8	5.5	6.4	1–10	2
Scovil Point	BF	12	33.3	2.8	3.5	1–8	4
Twin Lakes	BF	204	3.0	1.2	0.4	1–2	6
Barkers Point	GF	23	34.8	3.6	3.6	1–11	8
Black River	GF	194	14.9	3.4	4.6	1–22	29
Latimer Lake	GF	4	25.0	2.0			1
Twin Lakes	GF	13	7.7	4.0			1
Barkers Point	LF	73	28.8	4.3	3.4	1–13	21
Darlings Island	LF	5	60.0	4.3	3.1	1–7	3
Jemseg	LF	101	70.3	9.8	13.0	1–80	71
Scovil Point	LF	100	51.0	2.3	1.8	1–8	51
Acanthocephala							
<i>Fessisientis friedi</i>							
Scovil Point	BF	12	8.3	2.0			2
Jemseg	LF	101	3.0	1.0	0.0	1	3
Scovil Point	LF	100	1.0	1.0			1
<i>Neoechinorhynchus rutili</i>							
Twin Lakes	BF	204	0.5	3.0			1

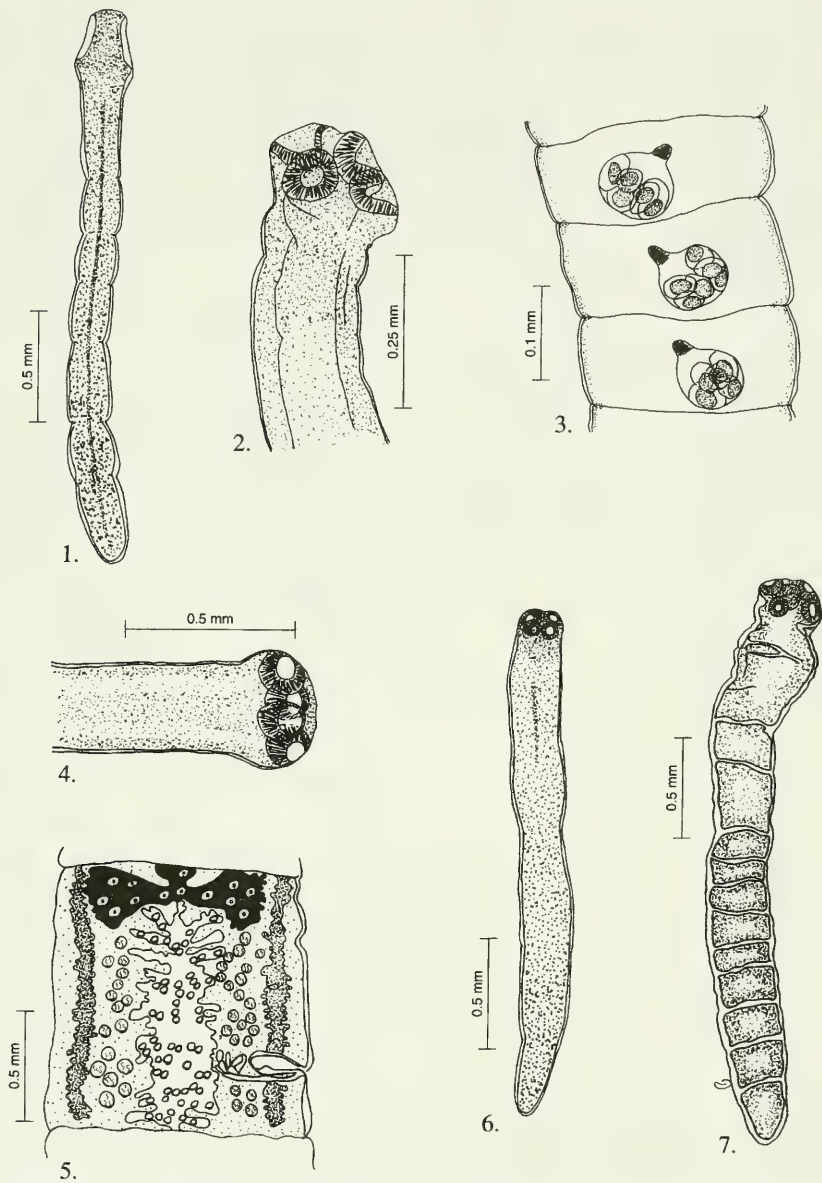
Table does not include 1 GF infected with 83 metacercaria tentatively assigned to *Gorgoderina attenuata*.

*Proteocephalid plerocercoids
(Figure 7)

R. catesbeiana, between mucosa and the muscular wall of stomach, *R. clamitans*, peritoneal cavity,

R. pipiens, between mucosa and the muscular wall of stomach, mesenteries near liver, peritoneal cavity.

Specimens collected agree with the description of



FIGURES 1-7. 1. *Bothriocephalus* sp., whole immature worm. 2. *Cylindrotaenia americana*, scolex. 3. *Cylindrotaenia americana*, pregravid proglottides showing position of paruterine organs. 4. *Proteocephalus saphena*, scolex. 5. *Proteocephalus saphena*, mature proglottis. 6. *Proteocephalus saphena*, juvenile worm. 7. *Proteocephalus* plerocercoid.

unidentified plerocercoids reported by Ulmer and James (1976). In all New Brunswick worms the apical organ is well developed. Although Ulmer and James (1976) noted evidence of immature proglottids in larger plerocercoids, in New Brunswick material this was evident only in a specimen of moderate length encysted near the liver in a Leopard Frog.

Previous definitive host records for proteo-

cephalid cysts and plerocercoids are summarized in Prudhoe and Bray (1982).

Digenea
Family Derogenidae Nicoll, 1910
**Halipegus occidualis* Stafford, 1905
(Figure 8)

R. catesbeiana, eustachian tube, stomach, duode-

num, ileum (immature forms only in gut), *R. clamitans*, eustachian tube, *R. pipiens*, immature forms only, in lower ileum and rectum.

All adult specimens of the genus *Halipegus* collected in this study were lodged in the eustachian tube and had eggs with filament lengths ranging from 53–65 μm (\bar{x} = 59 μm , n = 10 eggs from six worms). On this basis (see McAlpine and Burt 1998) all of these worms have been identified as *H. occidualis*.

Previous definitive host records are summarized in McAlpine and Burt (1998).

Family Strigeidae

**Apharyngostrigea pipientis* (Faust, 1918), Olivier, 1940 (Figure 9)

R. catesbeiana, mesenteries of ileum and urinary bladder, kidney surface, *R. clamitans*, mesenteries of ileum and urinary bladder *R. pipiens*, mesenteries of stomach, ileum and urinary bladder, kidney and lung surface, pericardium.

Specimens teased from cysts agree with the description and illustration presented in Hughes (1928). In New Brunswick, *A. pipientis* was particularly common in newly metamorphosed Leopard Frogs, one individual frog carrying 215 encysted metacercariae.

Previous second intermediate host records are summarized in Prudhoe and Bray (1982).

Family Diplostomatidae

***Alaria arisaemoides* Augustine and Uribe, 1927 (Figure 10)

R. catesbeiana, subcutaneously and intramuscularly in upper legs, stomach, lungs, between stomach mucosal and muscle wall, *R. pipiens*, subcutaneously and intramuscularly in upper legs.

Mesocercariae were identified according to Johnson (1970). The 2-3 rows of diagnostic acetabular spines are easily visible on mounted material. There are few reports of natural mesocercarial infections of *A. arisaemoides*. Leopard Frogs appear to become infected only by cercarial penetration of the skin. However, Bullfrogs are probably also infected via the gut when feeding on metamorphosing Leopard Frogs, hence the infection in the stomach wall and body cavity in *R. catesbeiana* noted above.

Previous mesocercarial infections are summarized in Prudhoe and Bray (1982) with the additions that follow. Freeman et al. (1976) report *A. arisaemoides* from Ontario, but do not mention whether one or all of three hosts examined, Bullfrog, Green Frog and Leopard Frog, were involved. However, Pearson (1956), also working in Ontario, found that mesocercariae of *A. arisaemoides* failed to develop in Green

Frogs although he carried out successful experimental infections of *A. arisaemoides* using *B. americanus*, *R. pipiens* and *R. sylvatica*. Although Hofer and Johnson (1970) obtained *A. arisaemoides* from naturally infected Leopard Frogs purchased from a Wisconsin supplier, the location where these frogs were collected is not stated.

Family Echinostomatidae

**Echinostoma trivolvis* (Cort, 1914), Kanev, 1985

(Figure 11 & 12)

R. catesbeiana, kidneys, *R. clamitans*, kidneys, *R. pipiens*, kidneys.

Worms encysted in the kidneys of frogs examined in this study were identified as *E. trivolvis* based on the examination of adults obtained through experimental infection, comparison with the work of Beaver (1937), and the recent revisionary work on the *E. revolutum* group by Kanev (1994). Although there are few records of *Echinostoma trivolvis* parasitic in amphibians, the species is reported to be widely distributed in North America (Kanev 1994) and is apparently the only 37 collar-spined echinostome currently known to encyst in North American amphibians. This was the most common helminth encountered in the three hosts in New Brunswick. The species was present at all sites collected, with prevalences of infection of 80% or over in more than half of the samples.

Frog kidneys often contained both transparent and melanized cysts, although one form was usually predominate. We found a complete lack of melanization of cysts in Leopard Frog (n = 169) kidneys. There was a significant but low correlation between the percentage of melanized metacercarial cysts in kidneys and increasing snout-vent length in Bullfrogs and Green Frogs (Spearman rank correlation coefficient, r_s = 0.34, p = 0.001, n = 237, r_s = 0.35, p = 0.04, n = 36). Martin and Conn (1990) found that melanized *E. trivolvis* cysts in frogs contained worms in various stages of decomposition. They speculated that darkened cysts may represent older infections or perhaps a species that is more susceptible to the host's immune response.

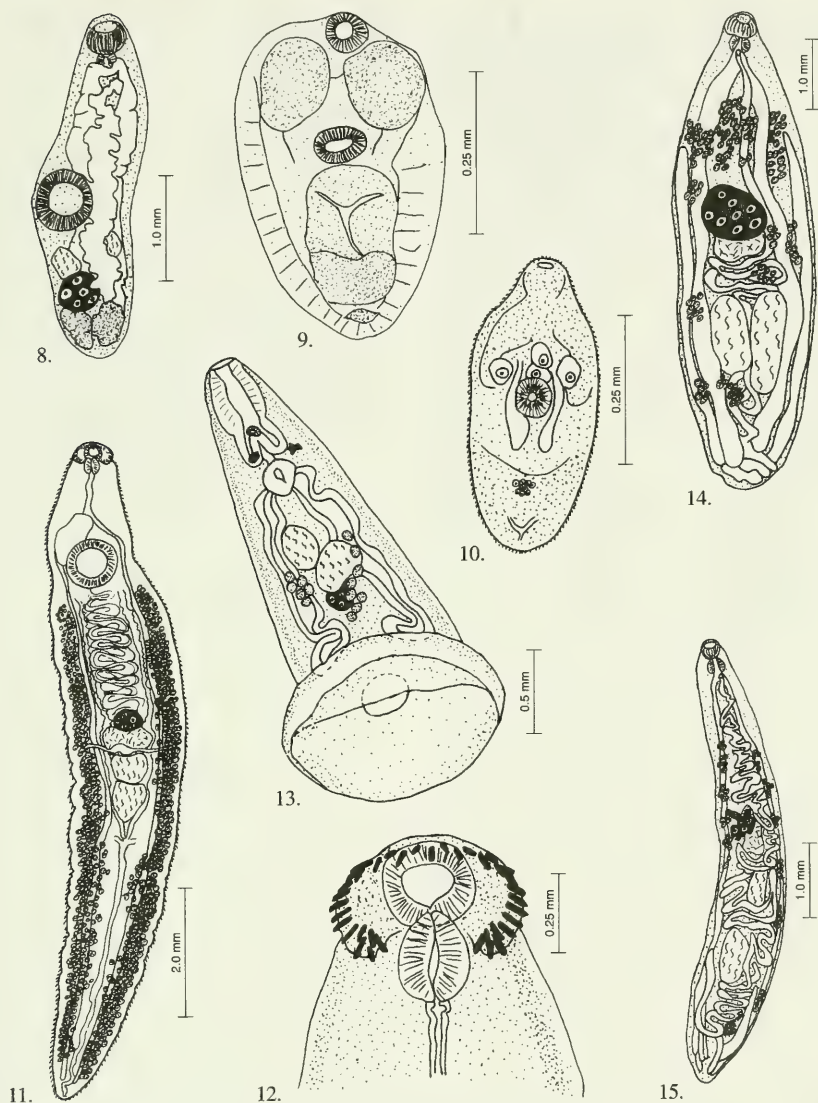
Previous second intermediate amphibian host records include: *R. pipiens* in Illinois (Beaver 1937) and New York (Martin and Conn 1990, personal communication to DFM). The species also utilizes various freshwater molluscs as second intermediate hosts (Beaver 1937; Schmidt and Fried 1996).

Family Paramphistomidae Fischöder, 1901

***Megalodiscus temperatus* (Stafford, 1905) (Figure 13)

R. catesbeiana, rectum, *R. clamitans*, rectum.

Harwood (1932) noted the wide host range among



FIGURES 8-15. 8. *Halipegus occidualis*, adult. 9. *Apharyngostrigea pipientis*, tetracotyle teased from cyst. 10. *Alaria arisaemoides*, metacercaria. 11. *Echinostoma trivolvis*, adult. 12. *Echinostoma trivolvis*, detail of anterior end. 13. *Megalodiscus temperatus*, adult. 14. *Haematoloechus longiplexus*, adult. 15. *Haematoloechus medioplexus*, adult.

amphistomes and the considerable morphological variability among his specimens of *M. temperatus*. Manter (1938) observed that "...contraction affects body proportions considerably in these worms." Although typically *M. temperatus* is triangular in shape with a posterior sucker that is wider than the body, 27 New Brunswick specimens show considerable variation in body proportions and the relative size of the posterior sucker. Nonetheless, all of these worms can be assigned to *M. temperatus* based on

the description of Stafford (1905). Price and Buttner (1982) reported their specimens as *M. rankini* but the deposited slide (USNPC 76349) is labelled *M. temperatus*.

Previous definitive host records are summarized in Brooks (1976) and Prudhoe and Bray (1982) with the following additions and corrections: *H. avivoca* in Arkansas (McAllister et al. 1993b); *R. catesbeiana* in Michigan (Fortner 1923; Muzzall 1991) and Ohio (Ashton and Rabalais 1978); *R.*

clamitans in Louisiana (Brooks 1979) and Michigan (Muzzall 1991); *R. pipiens* in Wisconsin (Williams and Taft 1980); *R. spheocephala* in Georgia (as *R. pipiens*, Parker 1941), Mississippi (as *R. utricularia*, Brooks 1979), North Carolina (Brandt 1936) and Tennessee (as *R. pipiens*, Parker 1941); *Notophthalmus viridescens* in Illinois (Price and Buttner 1982), North Carolina (Mann 1932) and Ohio (Kelley 1934); *Ambystoma opacum* in North Carolina (Mann 1932).

Brooks (1976) cites Stafford (1905) as a source of Ontario records in *B. americanus* (as *B. terrestris*) and *R. sylvatica* (as *R. cantabrigensis*). These records actually appear to be from Manter (1938) where no information on geographical location of collection is provided. Likewise, the compilation of Manter (1938) cited for Florida by Brooks (1976) provides no location information for *R. catesbeiana*, *R. gryllo* or *N. viridescens*. Similarly, Brooks (1976) is mistaken in his citation of Ingles (1936) as a source for *M. temperatus* in California *R. boylii*.

Family Haematoloechidae Odening, 1964
Haematoloechus longiplexus Stafford, 1902
(Figure 14)

R. catesbeiana, lungs, *R. clamitans*, lungs.

Haematoloechus species were identified according to the revision of Kennedy (1981). There were no multi-species infections of *Haematoloechus* in this study. In New Brunswick, *H. longiplexus*, as elsewhere, is principally a parasite of Bullfrogs. Kennedy (1980) found little geographical variation in this species. In only three of 40 New Brunswick specimens did extracaecal loops reach near the anterior border of the ovary. In all other specimens, the loops reached the posterior border of the pharynx, as described by Kennedy (1980). Mean infection rates/lung were 6.8 and 1.25 worms for the left lung and 5.0 and 1.7 for the right lung for Bullfrogs and Green Frogs respectively.

Previous definitive host records are summarized in Brooks (1976) and Prudhoe and Bray (1982) with the following additions and corrections: *R. catesbeiana* in British Columbia (Kennedy 1981), New Brunswick (Stafford 1902), Nova Scotia (Stafford 1902, Kennedy 1981), Ontario (Kennedy 1981), Quebec (Stafford 1902), Iowa (Kennedy 1981), Ohio (Ashton and Rabalais 1978), Oklahoma (Brooks 1979), Michigan (Muzzall 1991) and New York (Kennedy 1981); *R. clamitans* in Wisconsin (Williams and Taft 1980).

Brooks (1976) apparently considered *H. floedae* to be a synonym for *H. longiplexus*, citing Harwood (1932) for this latter species in *R. catesbeiana* and *R. clamitans* in Texas. However, Kennedy (1981) has synonymised *H. floedae* with *H. varioplexus*. Brooks (1976) mistakenly cites Manter (1938) as the source of Nebraska records for *H. longiplexus* in *R. catesbeiana*.

*****Haematoloechus medioplexus* (Stafford, 1902)**
(Figure 15)

R. pipiens, lungs.

Kennedy (1980) reports little variation in this species, which is most commonly a parasite of *R. pipiens*. *Haematoloechus medioplexus* was the only regularly occurring helminth in this study that was host specific, parasitizing only Leopard Frogs, at an overall prevalence of 13.4%. Kennedy (1981) distinguished *H. medioplexus* on the basis of an oral sucker/acetabulum (O/A) ratio of 2.0 or greater and a lack of extracaecal uterine loops. In a sample of 10 mature specimens from New Brunswick, O/A ratios ranged from 1:2.6 – 1:4.6 (\bar{x} = 1:3.8).

Previous definitive host records are summarized in Brooks (1976) and Prudhoe and Bray (1982) with the following additions: *B. americanus* in Alberta (Kennedy 1981); *R. pipiens* in Alberta and British Columbia (Kennedy 1981), Ontario (Kennedy 1981) Saskatchewan (Kennedy 1981), Iowa (Kennedy 1981) and Wisconsin (Kennedy 1981); *R. pretiosa* in British Columbia (Kennedy 1981).

*****Haematoloechus varioplexus* Stafford, 1902**
(Figure 16)

R. catesbeiana, lungs, *R. clamitans*, lungs, *R. pipiens*, lungs.

This is the most variable and geographically widespread North American member of the genus (Kennedy 1981). New Brunswick material agrees with the description of Kennedy (1981).

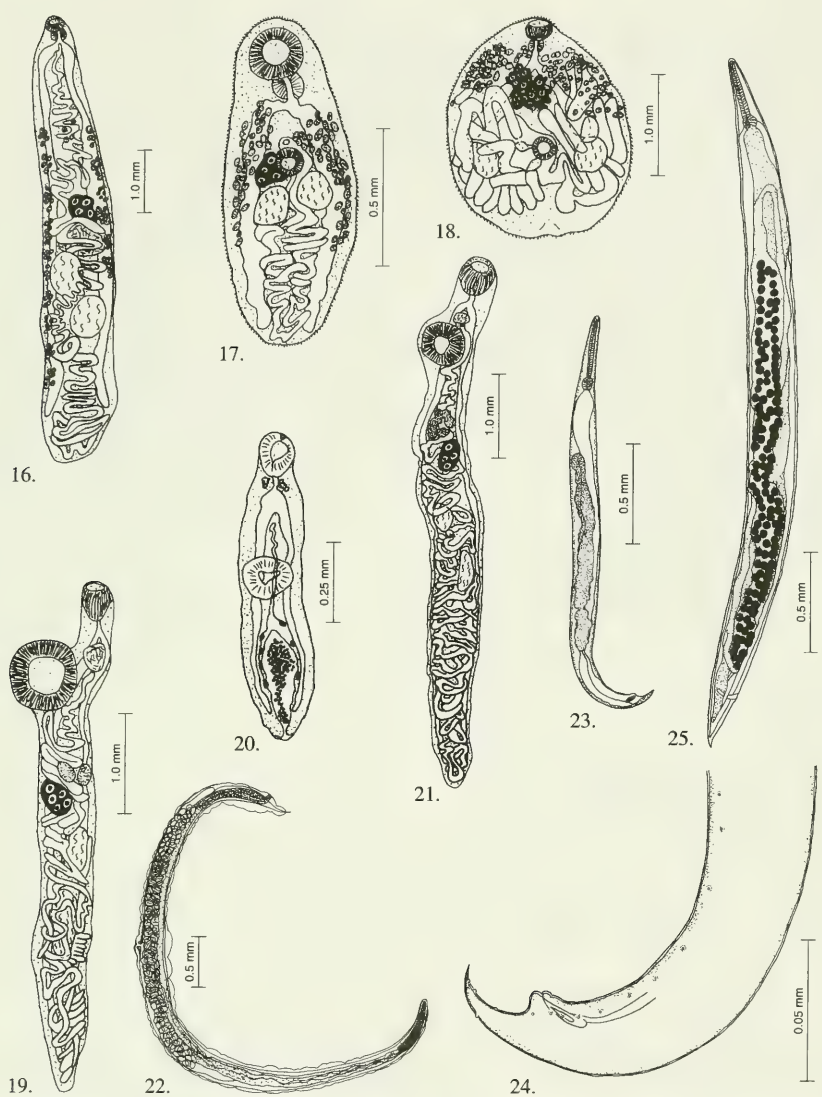
Previous definitive host records are summarized in Brooks (1976) and Prudhoe and Bray (1982) with the following additions: *R. boylii* in California (Ingles 1936); *R. catesbeiana* in Michigan (Muzzall 1991); *R. clamitans* in Ontario (Kennedy 1981), Michigan (Muzzall 1991) and Wisconsin (Williams and Taft 1980); *R. pipiens* in Wisconsin (Williams and Taft 1980); *R. pretiosa* in British Columbia (Kennedy, 1980, 1981) and Idaho (Russell and Wallace 1992); *R. sylvatica* in British Columbia (Kennedy 1981), Michigan (Muzzall and Peebles 1991) and Wisconsin (Yoder and Coggins 1996).

Family Macroderoididae

*****Glythelmins quieta* (Stafford, 1900)**
(Figure 17)

R. catesbeiana, ileum, *R. clamitans*, ileum, *R. pipiens*, ileum.

Previous definitive host records are summarized in Brooks (1976) and Prudhoe and Bray (1982) with the following additions and corrections: *R. aurora* in British Columbia (Moravec 1984); *R. catesbeiana* in Quebec (Rau et al. 1978), Michigan (Muzzall 1991), Oklahoma (Brooks 1979) and Texas (Dronen 1994); *R. clamitans* in Quebec (Rau et al. 1978), Louisiana (Brooks 1979), Michigan (Muzzall 1991) and Wisconsin (Williams and Taft 1980); *R. palustris* in



FIGURES 16–25. 16. *Haematoloechus varioplexus*, adult. 17. *Glyphelmis quieta*, adult. 18. *Loxogenes arcanum*, adult. 19. *Gorgoderina attenuata*, adult. 20. *Gorgoderina attenuata*, excysted metacercaria. 21. *Gorgoderina simplex*, adult. 22. *Rhabdias ranae*, adult. 23. *Cosmocercoides dukae*, adult male. 24. *Cosmocercoides dukae*, adult male showing rosette papillae on caudal section. 25. *Cosmocercoides dukae*, adult female.

Arkansas (McAllister et al. 1995b); *R. pipiens* in West Virginia (Brooks 1979) and Wisconsin (Williams and Taft 1980); *R. spheenocephala* in Louisiana (as *R. utricularia*, in Brooks (1979)) and Texas (Dronen 1994); *R. sylvatica* in Michigan (Muzzall and Peebles 1991).

Sullivan (1976) cites Rankin (1944) as the source of records for *G. quieta* in *R. catesbeiana* for Quebec, Massachusetts and North Carolina, but actually Rankin (1944) provides no information on host species and assigns worms to genus only.

Family Lecithodendriidae

*****Loxogenes arcanum* (Nickerson, 1900) Stafford, 1905 (Figure 18)**

R. catesbeiana, duodenum, *R. clamitans*, duodenum.

Previous definitive host records are summarized in Prudhoe and Bray (1982) with the following additions: *R. catesbeiana* in Michigan (Muzzall 1991); *R. clamitans* in Michigan (Muzzall 1991).

Family Gorgoderidae

*****Gorgoderina attenuata* (Stafford, 1902)**
(Figure 19 & 20)

R. catesbeiana, urinary bladder, *R. clamitans*, urinary bladder, encysted metacercaria in body cavity, *R. pipiens*, urinary bladder.

Gorgoderina attenuata was common at several sites and as many as 50 worms were removed from the urinary bladder of a single Leopard Frog. OVA ratios were 1:1.9 – 1:2.6 (\bar{x} = 1:2.3, n = 20) for New Brunswick specimens. Although *G. attenuata* and *G. simplex* occurred concurrently at the five sites where *Gorgoderina* were recorded, single infections involving both species were found at only two sites and were uncommon. One Bullfrog at Twin Lakes was infected with five and four worms of *G. attenuata* and *G. simplex* respectively, and one Bullfrog carried single worms of each species (prevalence = 2.5%). One Leopard Frog at Jemseg carried two and three worms of *G. attenuata* and *G. simplex* (prevalence = 10%). A single newly metamorphosed Green Frog at Barker's Point was parasitized with 83 *Gorgoderina* sp. encysted in the coelomic cavity. Metacercariae teased from cysts are tentatively assigned to *G. attenuata* based on the illustrations of Rankin (1939).

Previous definitive host records are summarized in Brooks (1976) and Prudhoe and Bray (1982) with the following additions and corrections: *R. catesbeiana* in Quebec (Rau et al. 1978), Michigan (Muzzall 1991) and Mississippi (Brooks 1979); *R. clamitans* in Quebec (Rau et al. 1978), Michigan (Muzzall 1991) and Wisconsin (Williams and Taft 1980, Coggins and Sajdak 1982); *R. pipiens* in Quebec (Rau et al. 1978) and Wisconsin (Williams and Taft 1980).

Brooks (1976) cites Rankin (1945) as a source for records in *R. sylvatica* (the only records of *Gorgoderina* in this host to date). However, Rankin (1945) reports gorgoderid cysts only and does not identify the species.

*****Gorgoderina simplex* (Looss, 1899)**
(Figure 21)

R. catesbeiana, urinary bladder, *R. clamitans*, urinary bladder, *R. pipiens*, urinary bladder.

Although not as wide-spread among sites or hosts as the previous species, *G. simplex* sometimes occur red at much higher prevalences. This species seems to show greater predilection for the two aquatic ranids, especially the Bullfrog, whereas *G. attenuata* was most common in the Leopard Frog. OVA ratios in adult worms were 1:1.1–1:1.4 (\bar{x} = 1:1.3, n = 20).

Previous definitive host records are summarized in Brooks (1976) and Prudhoe and Bray (1982) with the following additions: *R. clamitans* in Michigan (Muzzall 1991) and Wisconsin (Williams and Taft 1980).

Nematoda

Family Rhabdiasidae

*****Rhabdias ranae* Walton, 1929**
(Figure 22)

R. clamitans, lungs, *R. pipiens*, lungs, subadults in body cavity and rarely gut lumen.

Identification of lung worms was based on the work of Baker (1978). In addition to infections with adult worms, nine Leopard Frogs from Jemseg and two from Scovil Point were observed with subadult worms in the body cavity. On three other occasions, migrating worms had penetrated the intestinal wall and were found in the lumen of the intestine of Jemseg Leopard Frogs. At Jemseg and Scovil Point, 15.4% (n = 12) and 15.2% (n = 7) of *Rhabdias* infections were concurrent with infections of *H. medioplexus*. With the exception of five of these infections, *Rhabdias* predominated by ratios of 1:2.0 – 1:13.0 (\bar{x} = 1:7.4, n = 14).

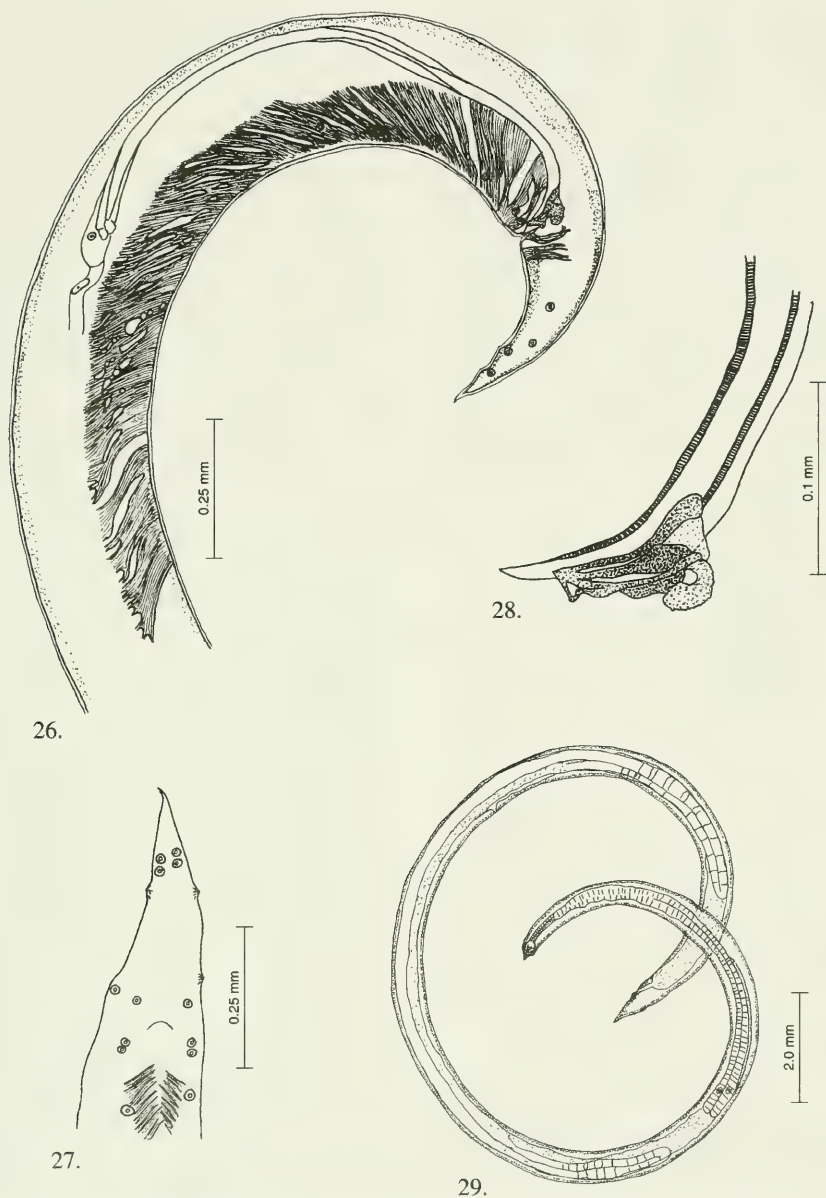
Previous definitive host records are summarized in Baker (1987) with the following additions: *A. gryllus* in Oklahoma (Trowbridge and Hefley 1934); *H. squirella* in Florida (Walton 1938); *P. brimleyi* in North Carolina (Brandt 1936); *P. crucifer* in Massachusetts (Rankin 1945), Michigan (Muzzall and Peebles 1991), North Carolina (Brandt 1936) and Wisconsin (Yoder and Coggins 1996); *Gastrophryne carolinensis* in Florida (Walton 1938); *R. catesbeiana* in North Carolina (Brandt 1936) and Texas (Hollis 1972; Dronen 1994); *R. clamitans* in Tennessee (Reiber 1941); *R. gryllo* in Florida (Walton 1938); *R. palustris* in Massachusetts (Rankin 1945); *R. pipiens* in Quebec (Rau et al. 1978), Florida (Reiber 1940), Ohio (Odlaug 1954), Oklahoma (Trowbridge and Hefley 1934) and Tennessee (Reiber 1941); *R. sphenoccephala* in North Carolina (Brandt 1936) and Oklahoma (Trowbridge and Hefley 1934); *R. sylvatica* in Massachusetts (Rankin 1945), Michigan (Muzzall and Peebles 1991) and Wisconsin (Yoder and Coggins 1996); *R. utricularia* in Texas (Dronen 1994); *A. laterale* in Michigan (Muzzall and Schindlerle 1992).

Based on the investigations of Baker (1978, 1979), reports by Walton (1938) of *R. ranae* in Florida *B. terrestris*, and records of Brandt (1936) in North Carolina *B. fowleri* and *Scaphiopus holbrookii* should presumably be referred to *R. americana*, while records of Rankin (1945) for *Lampropeltis triangulum* and *Thamnophis sirtalis* are more likely to be *R. fucovenosa*.

Family Cosmocercidae

*****Cosmocercoides dukae* (Holl, 1928)**
Travassos, 1931
(Figure 23, 24 & 25)

R. catesbeiana, rectum, *R. clamitans*, rectum, rarely ileum, *R. pipiens*, rectum, ileum.



FIGURES 26–29. 26. *Falcaustra inglisi*, posterior of male. 27. *Falcaustra inglisi*, detail of caudal section of male. 28. *Falcaustra inglisi*, detail of spicule. 29. *Spiroxys contorta*, third stage larva.

Cosmocercoides sp. in this study have been identified as *C. dukae* based on the papillar arrangement in male worms (Vanderburgh and Anderson 1987). The numbers of rosette papillae observed in New Brunswick material were: Bullfrog = 7 ($n = 1$), Green Frog = 11–14 ($\bar{x} = 12.2$, $n = 5$), Leopard Frog = 11–19 ($\bar{x} = 14$, $n = 8$). *Cosmocercoides dukae* was usually found in the posterior rectum,

but in heavy infections also occurred in the anterior rectum and posterior ileum.

C. dukae is normally a parasite of molluscs but is considered an accidental parasite in numerous species of frogs, salamanders, lizards, snakes and turtles (Baker 1987). Anderson (1960) has shown that infections of *C. dukae* in ranid frogs are short term and are the result of ingesting molluscs parasitized with the worm.

Based on the type description, Baker (1980) suggested, and later (Baker 1987) synonymized, *A. lynae* with *C. dukae*. The single male in the type series (NMCP 1900-1762) has 13 rosette papillae/row, identifying it as *C. dukae* based on the work of Vanderburgh and Anderson (1987), and confirming the synonymy suggested by Baker (1987).

Previous definitive amphibian and reptile host records are summarized in Baker (1987) with the following confirmed additions: *P. triseriata* (Muzzall and Peebles 1991); *R. catesbeiana* and *R. sylvatica* in Michigan (Muzzall and Peebles 1991) and Wisconsin (Yoder and Coggins 1996).

The studies of Vanderburgh and Anderson (1987) suggest that previous reports of *C. dukae* from bufonids should probably be assigned to *C. variabilis* while other amphibian hosts appear to be uncommonly infected with this species. Vanderburgh and Anderson (1987) were unable to infect *R. pipiens* with *C. variabilis*, but the species has apparently been found in hylid and microhylid frogs and McAllister et al. (1995b) report *C. variabilis* from *R. palustris*. However, the following should be added to the long list of unconfirmed reports of *C. dukae* listed by Baker (1987) that may include *C. variabilis*: *B. americanus* in Quebec (Fantham and Porter 1958); *G. olivacea* in Texas (McAllister and Upton 1987); *R. catesbeiana* in Texas (Dronen 1994); *R. clamitans* in Quebec (Fantham and Porter 1948); *Taricha granulosa* in California (Lehmann 1954); *N. viridescens* in New York and Pennsylvania (Fischthal 1955a,b); *Desmognathus fuscus* in Pennsylvania (Fischthal 1955b); *D. monticola*, *D. ochrophaeus* and *D. quadramaculatus* in North Carolina (Goater et al. 1987). Likewise, the reports of *C. variabilis* in *R. pipiens* by Odlaug (1954) and in *A. opacum* reported by Mann (1932) are more likely *C. dukae*, but remain unconfirmed.

Family Kathlaniidae

***Falcaustra inglisi* (Anderson, 1964) Baker, 1980

(Figure 26, 27 & 28)

R. catesbeiana, ileum, *R. clamitans*, ileum, anterior rectum.

New Brunswick reports are the first from outside the type locality in Algonquin Park, Ontario, where the species is parasitic in *R. catesbeiana* and *R. clamitans* (Baker 1986). New Brunswick specimens agree with the description of Anderson (1964), the re-description of Baker (1980), and with material deposited by Baker (1986) from Ontario (NMC 1985-0162) that we examined.

Family Gnathostomatidae

**Spiroxys contorta* (Rudolphi, 1819), Schneider, 1866

(Figure 29)

R. catesbeiana, encysted in stomach and ileum

wall, mesenteries of stomach, *R. pipiens*, encysted in stomach wall, mesenteries of ileum.

Worms recovered agree with the description of third stage larvae provided by Hedrick (1935). The rich chestnut colour of the intestine described by Hedrick (1935) is readily visible in worms teased from their encysted position in stomach walls.

Previous records of encysted larvae in second intermediate amphibian hosts include: *R. clamitans* in Michigan (Hedrick 1935); *N. viridescens* in Michigan (Hedrick 1935; Thomas 1937). Hedrick (1935) also recorded dragonfly larvae (probably *Sympetrum* sp.) and fish (*Ameiurus nebulosus* and *Umbra limi*) as second intermediate hosts.

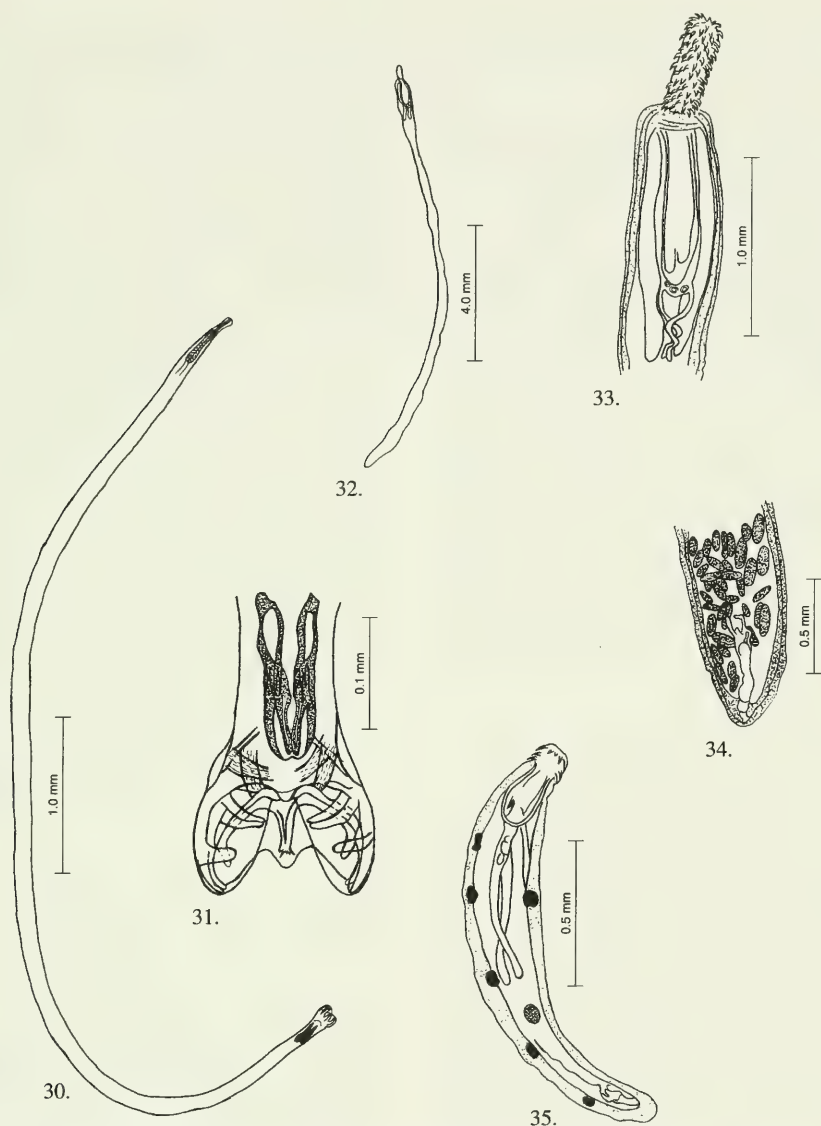
Family Molineidae

***Oswaldocruzia pipiens* Walton, 1929 (Figure 30 & 31)

R. catesbeiana, ileum, rarely anterior rectum, *R. clamitans*, ileum, rarely posterior stomach, *R. pipiens*, ileum, rarely anterior rectum and posterior stomach.

Baker (1977) redescribed *Oswaldocruzia pipiens* based on material collected from frogs in southern Ontario. New Brunswick material agrees with this redescription. *Oswaldocruzia pipiens* was common in Leopard Frogs at all sites where this host was sampled.

Previous definitive host records are summarized by Baker (1987) with the following additions: *B. alvarius* in Arizona (Goldberg and Bursey 1991a); *B. americanus* in Wisconsin (Coggins and Sajdak 1982); *B. cognatus* in Arizona (Goldberg and Bursey 1991a); *B. fowleri* in Massachusetts (Rankin 1945), North Carolina (Brandt 1936) and Tennessee (Reiber 1941); *B. punctatus* (Goldberg and Bursey 1991b); *B. woodhousei* in Oklahoma (Trowbridge and Hefley 1934); *S. couchii* in Arizona (Goldberg and Bursey 1991a); *S. holbrookii* in North Carolina (Brandt 1936); *H. avivoca* in Arkansas (McAllister et al. 1993b); *P. brimleyi* in North Carolina; *P. crucifer* in Massachusetts (Rankin 1945), Michigan (Muzzall and Peebles 1991) and North Carolina (Brandt 1936); *R. catesbeiana* in North Carolina (Brandt 1936), Oklahoma (Trowbridge and Hefley 1934) and Texas (Dronen 1994); *R. clamitans* in Massachusetts (Rankin 1945); *R. palustris* in Massachusetts (Rankin 1945) and Arkansas (McAllister et al. 1995b); *R. pipiens* in Ohio (Odlaug 1954) and Oklahoma (Trowbridge and Hefley 1934); *R. sphenoccephala* in North Carolina (Brandt 1936) and Oklahoma (Trowbridge and Hefley 1934); *R. sylvatica* in Massachusetts (Rankin 1945) and Michigan (Muzzall and Peebles 1991); *P. cinereus* in Massachusetts (Rankin 1945); *P. glutinosus* in North Carolina (Rankin 1937) and Wisconsin (Yoder and Coggins 1996); *D. fuscus* in Massachusetts (Rankin 1945) and Pennsylvania (Fischthal 1955b).



FIGURES 30–35. 30. *Oswaldocruzia pipiens*, adult male. 31. *Oswaldocruzia pipiens*, detail of caudal bursa. 32. *Fessisentis friedi*, whole worm. 33. *Fessisentis friedi*, anterior. 34. *Fessisentis friedi*, detail of female reproductive system. 35. *Neoechinorhynchus rutili*, whole worm.

Acanthocephala
Family Fessisentidae
Fessisentis friedi Nickol, 1972
(Figure 32, 33 & 34)

R. catesbeiana, ileum, three dead worms in mesenteries about ileum, *R. pipiens*, proboscis embedded in fold of urinary bladder on inside wall with 2/3 of body protruding into peritoneal cavity through bladder wall, duodenum, ileum with proboscis penetrating gut wall to coelomic cavity,

enclosed by membrane along outer ileum wall with proboscis penetrating to lumen of gut.

Campbell (1968) presents the single previous record of an adult acanthocephalan in a North American anuran (*Centrorhynchus wardae* in *R. clamitans*). Reports of Acanthocephala in North American amphibians are reviewed in McAlpine (1996).

Previous definitive host records include: *Necturus maculosus* in Michigan (Buckner and Nickol 1979);

plus six fish species in New Brunswick, New Hampshire and Pennsylvania (Buckner and Nickol 1979; Appy and Dadswell 1978).

Family Neoechinorhynchidae

Neoechinorhynchus rutili (Müller, 1780) Stiles and Hassall, 1905
(Figure 35)

R. catesbeiana, ileum.

Mühling (1898) reported that *E. clavaceps* (= *N. rutili*) was "verirrt sich nicht selten in den Darm des Frosches" [frequently found in the intestine of water frogs] in Germany. Walton (1942) interpreted this to mean the host *R. esculenta* (= *R. ridibunda* × *R. lessonae*) in Europe. Since the record here is only the second time this acanthocephalan has been reported in an amphibian host, the report of Mühling (1898) that the species was frequent seems unlikely. There are no previous records from North American amphibians (McAlpine 1996) although numerous fish species from across the northern hemisphere have been recorded as hosts for this parasite (Van Cleave and Lynch 1950). Canadian reports are summarized in Arai (1989). The infection reported here is considered accidental.

Discussion

Aho (1990) has reviewed previous studies and concluded that helminth communities in amphibians and reptiles are depauperate in species and have traits of non-interactive communities. Host specificity was low among the 23 species of helminths recorded in New Brunswick Bullfrogs, Green Frogs and Leopard Frogs, a feature that Aho (1990) suggested is characteristic of helminths parasitic in amphibians. The sometimes spectacular annual population fluctuations that anurans are noted for (Pechmann et al. 1991) may lead to local extinctions of particular host species, undoubtedly reinforcing these fluctuations. As Aho (1990) has suggested, amphibian helminths reduce the risk of extinction by parasitizing a reservoir of host species. Of the 23 helminths, 12 were found in all three frog species while only three were restricted to a single host. Two of these latter three, *Bothriocephalus* sp. and *Neoechinorhynchus rutili*, appear to be accidental infections. Although *Haematoloechus medioplexus* was only found to infect the Leopard Frog in New Brunswick, this digenean has been recorded in other anuran hosts elsewhere (Prudhoe and Bray 1982). The review and updating of previous host records presented here demonstrates that many of the helminths found in New Brunswick Bullfrogs, Green Frogs and Leopard Frogs infect a variety of amphibian hosts and are widely distributed in North America.

Although the three hosts share many of the same helminths, the importance of individual helminth

species within hosts varied. Encysted larval *Echinostoma trivolvis* was the most widely occurring helminth in all three frogs, however *Gorgoderina simplex* and *Haematoloechus longiplexus* were the second and third most widespread helminths infecting Bullfrogs, whereas *Glypthelmins quieta* and *Oswaldocruzia pipiens* similarly infected Green Frogs and *Oswaldocruzia pipiens* and *Rhabdias ranae* occupied these positions in the Leopard Frog.

Host ecology, operating along an aquatic-terrestrial host habitat gradient, seems to determine which taxa of helminths will predominate in these hosts. Digeneans with complex life-cycles dependant on aquatic intermediate hosts predominate in both species diversity and abundance in Bullfrogs and Green Frogs. However, in the more terrestrial Leopard Frog, nematodes with direct life-cycles are the most abundant and widespread adult helminth.

Many authors (cited in Ulmer and James 1976; as well as Williams and Taft 1980; Muzzall 1991b; McAllister et al. 1993b) have reported cestode prevalences of less than 10% in North American anuran helminth surveys, even when large numbers of hosts have been examined. Likewise, Prokopic and Krivanec (1975), in an extensive survey of Czechoslovakian amphibians recorded *Nematotaenia dispar* present in only 0.3% to 3.8% of aquatic anurans hosts. Lees (1962) examined over 2400 *R. temporaria* and Kuc and Sulgostowska (1988) examined 211 *R. ridibunda* and in neither study were any cestodes reported.

The low cestode prevalence in all three frog species in New Brunswick appears to be a feature of helminth communities in aquatic ranids. This may be a reflection of the generalist feeding habits of many aquatic frogs. In contrast, relatively high prevalences of tapeworms have been reported in the red spotted newt (Jarroll 1979; Muzzall 1991a), an active forager, as well as in bufonids (Brandt 1936; McAllister and Upton 1987; Goldberg and Bursey 1991a; Goldberg et al. 1995). Bufonids tend to be active, small prey specialists (Emerson 1985) whereas feeding behaviours in *Rana* appear to have evolved to support a diet of more varied prey size (McAlpine and Dilworth 1989; Anderson 1993).

The generalist feeding habits adopted by many anurans, combined with the relatively low metabolic rate (i.e., low rate of consumption of intermediate hosts) in amphibians, have led to the development of depauperate communities (Goater et al. 1987; Aho 1990). Bullfrogs, Green Frogs, and Leopard Frogs in New Brunswick follow this pattern. Also, there are a greater number of helminth species in New Brunswick Bullfrogs, the largest and most aquatic of the three ranid frogs examined. These features of New Brunswick Bullfrog, Green Frog, and Leopard Frog helminth communities agree with other studies

suggesting that host size, diet and habitat preferences are significant factors influencing the presence of helminths in amphibians (Brandt 1936; Combes 1972; Frandsen 1974; Prokopic and Krivanec 1975; Goater et al. 1987; Muzzall 1991). However, helminth species composition in frog hosts among New Brunswick sites is variable. This variation is certainly influenced by the presence or absence of hosts required in addition to frogs (itself dependant on the physical characters of wetlands) and the transmission dynamics of the helminth species involved (McAlpine 1997). For example, the presence of *Spiroxys contortus* at New Brunswick sites reported here correlates well with the distribution and abundance of turtle definitive hosts in the province (McAlpine and Godin 1986).

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Note added in proof;

Based on Canadian material, Ben Slimane and Durette-Desset (1997: Revision du genre *Oswaldocruzia* (Nematoda, Trichostrongylina, Molineoidea) en zone n arctique avec description de cinq nouvelles esp ces. *Zoosystema* 19: 61–79) have divided North American worms previously identified as *O. pipiens* into five species. Material on which our Figures 30–31 are based were taken from *Rana pipiens* and following re-examination of specimens we are able to assign these worms to *O. priceae* Ben Slimane and Durette-Desset, 1997. Further study is required to determine the status of *Oswaldocruzia* spp. from *R. catesbeiana* and *R. clamitans* in New Brunswick. Ben Slimane and Durette-Desset (1997) do not report examining *Oswaldocruzia* spp. from either of these hosts.

New Distribution Records of Aquatic Oligochaeta (Annelida) from Running Waters in Ontario

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Studies of oligochaetes in invertebrate collections at the Royal Ontario Museum resulted in new distribution records for several species of freshwater worms. Nearly 300 sites in Ontario rivers and streams were sampled with approximately 3000 specimens examined. Forty-three oligochaete taxa were identified, mostly naidids and tubificids but also including lumbriculids and one species of haplotaxid. *Nais variabilis* was the most common worm found, followed by *Limnodrilus hoffmeisteri*, *Stylaria lacustris*, *Tubifex tubifex*, and *Chaetogaster limnaei*. Specimens of *Limnodrilus tortilipenis*, previously known only from Illinois, were found in Ontario.

Key Words: Oligochaeta, Annelida, freshwater, distribution, Ontario, new records.

Oligochaetes are one of the most diverse and abundant benthic groups of organisms found in freshwater habitats (Brinkhurst 1986). The distribution and abundance of oligochaetes, especially tubificids, have been used to examine the water quality and environmental conditions of aquatic ecosystems (Stimpson et al. 1985; Schloesser et al. 1995). The role of oligochaetes as pollution indicators has often been discussed and the proportion of worms to other benthic invertebrates, as well as the relative abundance of various species of worms has been used to assess the degree of organic enrichment in lakes and rivers (Brinkhurst and Cook 1974; Brinkhurst 1980; Lauritsen et al. 1985; Milbrink 1994).

The distribution of freshwater oligochaetes in Ontario is poorly known. Of the detailed studies available, most cover local distributions (e.g., Brinkhurst 1970; Schloesser et al. 1995) or focus on the St. Lawrence Great Lakes (e.g., Brinkhurst et al. 1968) and not bodies of water from other drainages. Information on distributions from inland waters of eastern and northern Ontario is especially lacking. Brinkhurst and Jamieson (1971) summarized several studies of species in the Great Lakes while Spencer (1980) provided a thorough look at the systematics and zoogeography of Great Lakes populations. Spencer (1980) stated that the oligochaetes of the Great Lakes are well known because of the extensive research that has been conducted in the past, but he also pointed out that the species occurring in the streams, rivers, and smaller lakes of this region required more intense examination.

This paper is based on studies of oligochaetes in invertebrate collections donated to the Royal Ontario Museum (ROM) by the Ontario Ministry of Natural Resources (MNR) and the Ontario Ministry of the Environment (MOE) (currently the Ministry of

Environment and Energy). The MNR collection is a product of the MNR Aquatic Habitat Inventory Program which incorporated a standard set of field procedures for surveying the biological, chemical, and physical conditions of Ontario's rivers and streams (MNR 1989). The MOE collection involved the sampling of watersheds in and around the Metropolitan Toronto area including Toronto Harbour. This paper contributes information to the locations of species of oligochaetes in the rivers and streams of Ontario.

Methods

The MNR collection comprises benthic samples collected in the 1970s and 1980s, and the MOE collections consist of samples from the 1960s and 1970s. The MNR districts (as they were in 1981) for which oligochaete samples were available (Figure 1) cover most aquatic habitats of southern and eastern Ontario. Districts that have no oligochaete information either were lacking invertebrate samples or there were no identifiable oligochaete specimens in the samples. Some of the samples in the MOE collection were without detailed location information. For these samples, the latitudes and longitudes reported in the *Gazetteer of Canada* (1988) for the waterbody were used.

All sites (except for Toronto Harbour) were in rivers and streams and samples were collected from a variety of habitats (e.g., pools, riffles) with specific details not always documented. Invertebrate samples were collected during the MNR and MOE programs by a variety of techniques. Qualitative sampling methods included hand picking of specimens, D-frame nets, and hand sieving. Quantitative techniques included use of a surber sampler, Petersen dredge, and Ekman dredge. Samples were fixed by

TABLE 1. Distribution of freshwater oligochaetes for each drainage area and the percent occurrence (presence/total number of locations) in Ontario. Species are grouped according to the assigned distribution category.

	PERCENT OCCURRENCE	Winnipeg River (Lake Winnipeg)	Lake Superior	James Bay	North Channel (Lake Huron)	Georgian Bay, Lake Huron, Lake Simcoe	Ottawa River	St. Lawrence River, Lake St. Lawrence	Niagara River, Lake Ontario, Trent-Severn	Lake St. Clair, Lake Erie
WIDESPREAD										
Tubificidae:										
<i>Ilyodrilus templetoni</i>	1.7		x		x				x	
<i>Limnodrilus hoffmeisteri</i>	19.7		x	x	x	x	x	x	x	x
<i>Limnodrilus udekemianus</i>	4.7			x	x			x	x	
<i>Tubifex tubifex</i>	11.2			x	x	x	x	x	x	x
Naididae:										
<i>Arcteonais lomondi</i>	5.4		x	x	x	x	x	x		
<i>Chaetogaster limnaei</i>	9.8			x	x	x	x	x	x	
<i>Nais communis</i>	7.1		x	x	x	x	x	x	x	x
<i>Nais simplex</i>	2.4		x			x		x		
<i>Nais variabilis</i>	26.8		x		x	x	x	x	x	x
<i>Slavina appendiculata</i>	5.1		x	x	x	x	x	x		
Lumbriculidae:										
<i>Stylodrilus heringianus</i>	7.8		x		x	x	x		x	x
NORTH/NORTHEASTERN										
Naididae:										
<i>Stylaria lacustris</i>	15.6	x	x	x	x	x	x	x	x	
<i>Uncinails uncinata</i>	1.0			x	x					
CENTRAL										
Naididae:										
<i>Chaetogaster diaphanus</i>	2.4				x	x	x	x		
<i>Chaetogaster diastrophus</i>	1.7					x	x			
<i>Nais pardalis</i>	1.0					x				
SOUTH CENTRAL										
Tubificidae:										
<i>Aulodrilus pigueti</i>	1.0					x		x	x	
Naididae:										
<i>Nais behningi</i>	2.7					x		x		x
<i>Nais bretscheri</i>	8.1				x	x	x		x	x
<i>Nais elinguis</i>	5.4				x	x	x	x	x	x
SOUTHERN										
Tubificidae:										
<i>Branchiura sowerbyi</i>	1.0						x		x	
<i>Limnodrilus cervix</i>	2.4								x	x
<i>Limnodrilus claparedianus</i>	2.4						x	x	x	x
<i>Spirosperma ferox</i>	1.0							x		
Naididae:										
<i>Dero digitata</i>	1.0								x	x
<i>Ophidonais serpentina</i>	6.1						x	x	x	x
INFREQUENT (< 3 sample points)										
Tubificidae:										
<i>Aulodrilus limnobius</i>	0.7								x	
<i>Aulodrilus pluriseta</i>	0.7		x						x	
<i>Isochaetides freyi</i>	0.3				x					
<i>Limnodrilus tortilipenis</i>	0.3								x	
<i>Potamothrix moldaviensis</i>	0.7					x				x
<i>Quistadrilus multisetosus</i>	0.7								x	
<i>Quistadrilus m. longidentus</i>	0.7									x
<i>Rhyacodrilus coccineus</i>	0.7					x	x			

(Continued)

TABLE 1. *Concluded.*

	PERCENT OCCURRENCE	Winnipeg River (Lake Winnipeg)	Lake Superior	James Bay	North Channel (Lake Huron)	Georgian Bay, Lake Huron, Lake Simcoe	Ottawa River	St. Lawrence River, Lake St. Lawrence	Niagara River, Lake Ontario, Trent-Severn	Lake St. Clair, Lake Erie
INFREQUENT (< 3 sample points) (continued)										
Naididae:										
<i>Dero nivea</i>	0.3				x					
<i>Nais barbata</i>	0.3								x	
<i>Piguetiella michiganensis</i>	0.3					x				
<i>Pristina aequisetata</i>	0.7		x					x		
<i>Pristina leidy</i>	0.3						x			
<i>Vejdovskyella comata</i>	0.7						x		x	
Lumbriculidae:										
<i>Eclipidrilus lacustris</i>	0.7							x	x	
<i>Lumbriculus variegatus</i>	0.3		x							
Haplotaxidae:										
<i>Haplotaxis gordioides</i>	0.3									x
Total Number of Taxa		1	12	9	17	20	19	20	24	15
Number of Locations Sampled		1	15	10	21	80	60	31	38	38

MNR or MOE staff in Bouin's solution, Kahle's solution, 10% buffered formalin, and/or 70% ethanol and preserved in 70% ethanol. ROM staff sorted samples for identification. We found that samples that had been originally fixed in Kahle's solution or formalin resulted in well preserved worm specimens. Oligochaetes were stained using Grenacher's alcoholic borax carmine solution and destained with an acid alcohol solution. Specimens were dehydrated using an alcohol series and cleared with xylene. Each specimen was mounted in Canada balsam on a glass microscope slide. Oligochaetes were identified using an interference contrast microscope (Wild-Leitz Dialux 22). Specimens are stored at the Centre for Biodiversity and Conservation Biology, Royal Ontario Museum (Catalogue numbers: ROMIZ I2196, ROMIZ I2199 to ROMIZ I2201, ROMIZ I2203, ROMIZ I2209, ROMIZ I2211, ROMIZ I2216, ROMIZ I3308 to ROMIZ I4257, ROMIZ I4294 to ROMIZ I4362).

Results

Oligochaete records were available for 295 locations in Ontario. Roughly 3000 specimens were identified, comprising 43 oligochaete taxa. Most were naidids (22 species), followed by tubificids (16 species and one subspecies), lumbriculids (three species), and one species of haplotaxid (Table 1). Spencer (1980) reported 40 naidid, 37 tubificid, four lumbriculid, and one haplotaxid species/subspecies

for the St. Lawrence Great Lakes region. Our samples include almost one-third of the naidid and one-third of the tubificid species recognized in North America (Brinkhurst 1986). The details of locations of each species can be obtained from the Centre for Biodiversity and Conservation Biology, Royal Ontario Museum (Accession numbers: 1989-016, 1989-017, 1989-026, 1989-034, 1989-041, 1989-042, 1989-055, 1990-018, 1993-019).

The waterbodies sampled were grouped into nine major drainage basins, to facilitate species distribution comparisons, using Cox (1978) (Table 1). The Niagara River/Lake Ontario/Trent-Severn drainage contained the most species of worms (24 species), followed by the Georgian Bay/Lake Huron/Lake Simcoe and the St. Lawrence River/Lake St. Lawrence drainages (20 species, each), the Ottawa River drainage (19 species), the North Channel (Lake Huron) drainage (17 species), the Lake St. Clair/Lake Erie drainage (15 species), the Lake Superior drainage (12 species), the James Bay drainage (9 species) and the Winnipeg River (Lake Winnipeg) drainage (1 species) (Table 1).

The species which occurred most frequently over the whole sampling area was *Nais variabilis* (26.8% of sites) (Table 1). *Limnodrilus hoffmeisteri* (19.7% of sites) was the next most commonly found worm, followed by *Stylaria lacustris* (15.6% of sites), *Tubifex tubifex* (11.2% of sites), and *Chaetogaster limnaei* (9.8% of sites) (Table 1).

Maps were plotted of sample locations for each species using ArcView® (Environmental Systems Research Institute, Inc.) and were used to assign distribution categories to the species (Table 1). Categories were determined by visually assessing the pattern of locations on each species' map. Species were categorized as either widespread, northern/northeastern, central, south central, or southern in distribution. Widespread species had locations that appeared to be distributed throughout Ontario. Species of the northern/northeastern category were located mostly in areas draining into the northern Great Lakes and the Ottawa River. Central species were found in the rivers near Lake Huron and the Ottawa River. The south central species had a similar distribution to the central ones, except they also occurred in the tributaries of the lower Great Lakes. Species found only from drainages of the lower Great Lakes were categorized as southern. Species for which there were less than three sample points were not used in the distribution categories, but were considered to be infrequent.

Eleven species were widely distributed in Ontario (Table 1). Many of these were also the most commonly encountered species in Ontario (e.g., *N. variabilis*, *L. hoffmeisteri*, *T. tubifex*, *C. limnaei*) (Table 1). *Stylaria lacustris* appeared to be restricted to northern/northeastern areas in Ontario and *Uncinaxis uncinata* to northern Ontario (Table 1). Three species had central distributions and four had south central distributions (Table 1). Six species had southern distributions (Table 1). The remaining 17 taxa were infrequent (Table 1).

We found *Limnodrilus tortilipenis* in the Don River (Lake Ontario drainage), a new location record for this species. It is previously known only from Illinois (M. J. Wetzel, Illinois Natural History Survey, Illinois, personal communication).

Discussion

Both the MNR and the MOE collections are valuable as a source of detailed information on the distribution of invertebrates from waterbodies in Ontario. Few publications, if any, exist which specify aquatic oligochaete species occurrence and distribution in the whole of Ontario. Oligochaete species can often make up a large part of the total taxa found in aquatic habitats (Barton 1986). They can be responsible for the bioturbation of lake sediments, affecting the nutrient dynamics of the system (Brinkhurst and Cook 1974). Some are good environmental indicators (Lauritsen et al. 1985). Such biotic information is useful to government agencies as well as many museum, academic, and private sector researchers for monitoring distributions and environmental changes.

Although the presence of a species is certain, the absence of a species is not and could be due to a number of factors including a disproportionate sampling effort, the environmental requirements of the species, and the connectivity of habitats. Many

methods can be used to collect oligochaetes with some recognized as better than others (Klemm 1985; Brinkhurst and Gelder 1991). Several techniques were used within each MNR district which may be important in accounting for the differences in species distribution observed. Standardized collection techniques, while desirable, are often lacking in museum collections. The number of sampling locations vary among the drainage areas from one site, in the Winnipeg River (Lake Winnipeg) drainage, to 80 locations, in the Georgian Bay/Lake Huron/Lake Simcoe drainage (Table 1). Although increasing the number of sampling sites may not necessarily lead to a greater diversity of oligochaete species, it is clear that several regions, particularly in the northwest, require additional study.

The environmental requirements of a species can dictate its distribution. Oligochaete species distribution has been found to vary with food material (organic matter and microflora) available in sediments, water quality conditions, and substrate type (Brinkhurst and Gelder 1991; Casellato and Caneva 1994; Diaz and Erséus 1994). Likely, differences in habitat type among the sites sampled, may have imposed limitations on species distributions.

Almost all of the drainage areas drain into the St. Lawrence Great Lakes (Table 1, Figure 1), potentially connecting oligochaete habitats on a large scale. But two drainage areas, Winnipeg River (Lake Winnipeg) and James Bay, drain elsewhere which could affect a species' distribution and the patterns we encountered. These two areas had the lowest number of taxa, but, they also had the fewest number of sites sampled (Table 1). Perhaps, rather than habitat connectivity, the low species diversity observed could be a function of sampling effort.

We found a diverse group of oligochaetes in Ontario, some of which have noteworthy and varying distributions. For example, *S. lacustris* was not found in southern and southwestern Ontario. Spencer (1980) and Schloesser et al. (1995) listed this species as occurring in Lake Erie but it was not found in our samples from running waters of this region. This nauid is known to be widely distributed in North America but is more common in northern locations of the continent (Brinkhurst 1986; Brinkhurst and Gelder 1991).

Another striking distribution pattern is that of the southern species: *Branchiura sowerbyi*, *L. cervix*, *L. clapedianus*, *Spirosperma ferox*, *Dero digitata* and *Ophidonais serpentina* (Table 1). These species were restricted to the southern most drainage areas of the province. Brinkhurst and Jamieson (1971) stated that *L. cervix* is confined to the lower Great Lakes; however, Spencer (1980) reported *L. cervix*, *L. clapedianus*, and *S. ferox* as being found in all of the Great Lakes. These species may have wider distributions than those we found. *Dero digitata* is reported from all the Great Lakes except Lake Ontario (Spencer 1980), but we have a record of this nauid from the



FIGURE 1. Map of Ontario showing the MNR districts. Hatched areas indicate districts without oligochaete specimens.

Don River. Spencer (1980) reported *B. sowerbyi* from Lake St. Clair and Lake Erie and we found this species in samples from southern rivers which drain into the Ottawa River and the Niagara River. Apparently, this species has a southern distribution in Ontario. *Branchiura sowerbyi* thrives in man-made lakes and streams, where water temperature is elevated, but is now found in temperate waters across North America (Brinkhurst and Gelder 1991).

Many species are widespread (Table 1). The species we designated in this category, in most cases, occur in each of the Great Lakes (Spencer 1980). For those species which were not found in specific Great Lakes, according to Spencer (1980), our records place them in watersheds draining into the lake. For example, we found samples of *C. limnaei* in rivers from the Lake Huron drainage and *N. variabilis* in rivers from the Lake Erie drainage which were not indicated in Spencer's (1980) records. *Uncinaiis uncinata* is reportedly quite widespread in the Great Lakes (Spencer 1980; Hiltunen and Klemm 1985) but we found it only in northern waters.

Some of the taxa we labelled as infrequent are likely more common when compared with records for Great Lakes populations. For example, *Aulodrilus limnobius*, *A. pluriseta*, *Isochaetides freyi*, *Quistadrilus multisetosus*, *Piguetiella michiganensis*, *Pristina leidy*, and *Lumbriculus variegatus* are known from the St. Lawrence Great Lakes, in some cases, quite abundantly (Brinkhurst and Cook 1974; Spencer 1980; Hiltunen and Klemm 1985; Stimpson et al. 1985). Other studies (see Brinkhurst and Jamieson 1971 and references cited within) indicate distributions for *Potamotheix* and *Rhyacodrilus* wider than those we have documented. As such, these taxa are likely not rare but under-represented by our collections.

Some species are recognized as rare in Ontario and the Great Lakes. For example, *Haplotaxis gordioides* is rare in the Great Lakes (Spencer 1980) and it is not surprising that we only found one specimen, from Big Otter Creek which drains into Lake Erie. This species is known from subterranean waters (springs, groundwater, seepages, and wells) but has been found in other localities (Brinkhurst and Jamieson 1971). Our speci-

men was collected using a surber sampler in a surface water location. We have a record for *Eclipidrilus lacustris*, another infrequently found species, from the Trent-Severn Waterway and from a tributary of the St. Lawrence River, which add to Spencer's (1980) records from Ontario. Additional sampling of the Don River watershed could lend insight into the nature of the range extension of *L. tortilipenis*. Samples of this species were collected in 1966.

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Effects of Supplemental Feeding on White-tailed Deer, *Odocoileus virginianus*, Migration and Survival in Northern Wisconsin

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From 1986–1989, we increased food available to free-ranging deer on either summer range ($n = 53$ deer) or winter range ($n = 66$) and compared these to deer that received no supplemental feeding (control, $n = 48$) in the Chequamegon National Forest in northwestern Wisconsin. Winter feeding had no effect on the timing of spring migration, although fewer supplementally fed deer migrated. Summer feeding delayed migration to wintering areas ($\bar{x} = 5$ days). Home range was not affected by feeding regime. Winter-fed deer had higher average annual survival rates than unfed or summer-fed deer ($\bar{x} = 0.78$ vs. 0.64 and 0.53, respectively). Supplementally-fed deer had higher average winter survival than unfed deer only during the severe winter of 1988–89 ($\bar{x} = 1.00$ and 0.96 for winter and summer-fed deer vs. 0.79 for unfed deer). Summer-fed does had lower summer survival rates ($\bar{x} = 0.58$) than winter-fed does ($\bar{x} = 0.84$) or control does ($\bar{x} = 0.92$) because of increased vulnerability to hunting. Supplemental feeding had a slightly positive impact on survival and a marginal effect on migration. As recreational or supplemental feeding increases, there may be long-term impacts on migratory behavior.

Key Words: White-tailed Deer, *Odocoileus virginianus*, supplemental feeding, migration, winter survival, Wisconsin.

During winter the public often requests that wildlife management agencies begin emergency feeding of ungulates. Private feeding operations, especially for birds, White-Tailed Deer (*Odocoileus virginianus*), and Mule Deer (*O. hemionus*), have become popular. While those feeding wildlife are usually concerned with the benefits to individual animals and their own viewing pleasure, the population-level effects of these activities are largely unmeasured. Most such recreational feeding occurs throughout the autumn and winter, and its effects may be different than emergency feeding, which is usually begun late in the winter during protracted, adverse weather. Supplemental foods frequently include corn, grain, vegetables, and commercial deer pellets. Concerns have been raised that recreational feeding may hold deer on suboptimal range and that it might be ineffective.

Emergency deer feeding practiced by government agencies and many hunting organizations is different from recreational feeding. Emergency feeding has not proven to be a successful technique for reducing over-winter mortality despite decades of extensive trials (e.g. Carhart 1943; Doman and Rasmussen 1944; Dahlberg and Guettinger 1956; Keiss and Smith 1966). Emergency feeding often leads to rumenitis or carbohydrate overload (Woolf and Kradel 1977; Wobeser and Runge 1975). However, emergency feeding has occasionally recuperated starving deer (Ullrey et al. 1969; Baker and Hobbs 1985). Lenarz (1991) determined that the costs of emergency feeding per deer saved are so high that its use is not justified. Besides the obvious monetary

drain for food and persons to distribute food, increasing food supplied in either recreational or in an emergency feeding situation can locally concentrate deer populations and lead to over-browsing. Thus Leopold (1943) referred to supplemental deer food as a "...net subtraction from the food available." Schmitz (1990) found that supplemental feeding creates a limiting resource by concentrating food in a limited number of feeders.

Recent research on the effects of supplemental feeding has determined fed deer exhibited increased body (Ozoga and Verme 1982) and antler growth (Geist 1986), lower secondary sex ratios (Robinette et al. 1973; Verme 1969; Ozoga and Verme 1982), and increased fecundity (Verme 1965; Ozoga and Verme 1982). Supplemental feeding artificially increased carrying capacity of deer range in Michigan (Ozoga and Verme 1982), probably, in part, by increasing digestibility of foods (McCullough 1979; Ullrey et al. 1971).

Given these known physiological and habitat effects in closely studied captive deer, comparisons to free-ranging deer seem necessary. Studies focusing on free-ranging deer have measured use of supplemental food blocks by unconfined, yarding deer (Anderson et al. 1975), although survival effects were not measured. The degree to which herd improvements shown in captive deer transfer to free-ranging deer has implications for agencies working with an animal-feeding public and to biologists concerned with the effects of this additional food within the ecosystem. We tested for changes in the timing and distance of seasonal migration, home range size,

and seasonal survival of two different groups of supplementally fed deer and unfed deer.

Study Area

The study was conducted during 1986-1989, although monitoring of radio transmitters has continued up to six additional years on some animals. We selected an area in and adjacent to the Chequamegon National Forest in northwestern Wisconsin where deer feeding had occurred annually for > 5 years in areas reported to have had wintering deer for > 30 years (Dahlberg and Guettinger 1956). The Chequamegon National Forest has gently rolling hills with mixed hardwoods and lowlands with mixed conifer swamps. Timber is the main commodity produced on the forest, and no commercial agriculture occurs in the study area. Forest cover types on the Chequamegon National Forest included 26% aspen (*Populus* spp.), 11% mixed northern hardwoods [including: Red Oak (*Quercus rubra*), Paper Birch (*Betula papyrifera*), and scrub oak (*Quercus* spp.)], 27% maple (*Acer* spp.), 8% Red Pine (*Pinus resinosa*), 6% Jack Pine (*Pinus banksiana*), 6% Balsam Fir (*Abies balsamea*), 2% White Spruce (*Picea glauca*), 1% White Pine (*Pinus strobus*), 11% swamp conifer/hardwoods [including White Cedar (*Thuja occidentalis*) and Eastern Hemlock (*Tsuga canadensis*)] and 2% permanent openings (U.S.D.A. Forest Service 1986).

The Chequamegon National Forest was lightly hunted during the study. The fire-arms season spanned nine days around Thanksgiving each November, and the archery season ran from September through December, exclusive of the fire-arms season. Other recreational uses of the area include fishing, small game hunting, hiking, and off-road vehicle use (U.S.D.A. Forest Service 1986). Deer populations peaked in this area after heavy logging at the end of the 19th century, then declined steadily until the 1950s (Dahlberg and Guettinger 1956). During the years of this study, deer populations in the study area, and across northern Wisconsin increased rapidly (Wisconsin Department of Natural Resources unpublished data).

Methods

In order to test the effects of recreational feeding, we supplemented food to one group of deer on their summer range. A second group received supplemental food on their winter range. A third group received no supplemental food and served as a control. All study animals except 24 of 66 winter-supplemented deer were located in a contiguous area 15 km by 30 km, with overlapping summer and winter ranges. We made no attempt to assign deer to a feeding group, but rather observed feeders to determine which deer received supplemental food. Although this precluded a perfectly randomized study design, it did take advantage of the long-term feeding in the area. We assumed no differences between deer in the different

feeding groups based on the overlapping home ranges of deer from the three groups, the ready availability of feeders, and the fact that some deer switched groups between feeding regimes during different seasons.

We used three sets of feeders that had been in use for many years (7 at Spider Lake, >20 at Beaverdam Lake and >40 at Long Lake, 40 km south of Spider Lake), where deer were habituated to feeder use. We chose these feeding sites because they were located where the deer would be observable from homes at the feeding sites, yet isolated from other homes where feeding could occur. Control deer were located in the same areas as both groups of experimental deer, but did not use the feeders. We compared seasonal movements and survival among these groups.

The first experimental group, consisting of 53 deer, received *ad libitum* shelled corn at Beaverdam Lake, west of Mellen, Wisconsin, from mid-April until mid-December at which time deer migrated to winter range. Although referred to as "summer" feeding, deer used this food primarily in early spring and late autumn, and migrated away for the winter, including to the Spider Lake area.

The second experimental group, 66 deer, received *ad libitum* shelled corn on winter range at Spider Lake (42 deer) from 1 December until 30 April or were fed commercial deer food (Doboy Deer Pellets, Domain, Inc., New Richmond, Wisconsin) twice daily during the same winter period at Long Lake (24 deer). Corn and commercial pellets were nutritionally similar, were both widely used near the study area, and supplemented naturally available browse. We chose Spider Lake for winter feeding because many of the deer from around the summer feeders wintered in that area. Long Lake deer were observed and included in this study, although none of those deer shared summer or winter ranges with the other study animals (except two dispersing males from the Spider Lake area). While the habitat at Long Lake was similar to the remainder of the study area, severe over-browsing was evident. The timing of migration and interval survival rates for Long Lake deer were not different from the Spider Lake deer ($P > 0.05$), and results were pooled for analysis. Inclusion of these deer from analysis did not change the mean of the results, but did decrease estimated variance by increasing sample size.

The control group, 48 deer, were captured near (<2 km) both Spider Lake and Beaverdam Lake feeders. These deer had home ranges that were near to the feeders, yet they did not use feeders. None were observed at, nor radio-located within 300 m of a feeder. Although the experimental design did not preclude it, no deer were winter-fed and summer-fed in the same year.

We placed corn and pellets in trough or hopper feeders, or directly on the ground. We used 2-6

feeders in a 1 ha area to minimize aggression between deer. There were some acts of aggression at the feeding sites that could have temporarily excluded deer, although typically aggression only changed the order of feeding. Schmitz (1990) found interference competition at feeders seemed to force some deer to seek food elsewhere.

All study deer were captured either with Clover traps ($n = 160$, Clover 1956) or rocket nets ($n = 9$, Hawkins et al. 1968). Two additional fawns died < 1 week after capture and were excluded from all analysis. Deer were marked with 1 or 2 numbered metal strap tags and a radio-transmitter. Trapping locations were all < 4 km and typically < 2 km from feeding locations at Beaverdam Lake, Spider Lake, and Long Lake. Trapping on summer range at Beaverdam Lake occurred from 1 September until the deer left summer range for winter range, usually in late November. Trapping on winter range at Spider Lake occurred from 1 January until 1 April and at Long Lake in March. At capture, deer were sexed and classed as adult (≥ 1 year) or fawn (< 1 year old). We baited traps with corn, cedar boughs, and apples, and checked them several times daily both visually and by checking radio-transmitters on traps that ceased transmitting when the door closed.

Doe and doe fawns were equipped with lithium-battery powered radio-transmitters with mortality sensors attached to collars (Advanced Telemetry Systems, Inc., Isanti, Minnesota (ATS)). Bucks and buck fawns were equipped with solar-powered radio-transmitters (Telemetry Systems, Inc., Mequon, Wisconsin, and ATS) epoxied onto cattle ear tags, and clipped into the ear. Complete solar transmitter packages weighed 20-30 g. Radio collars were marked with a letter or number in order to identify individual deer at feeders, but were otherwise brown and inconspicuous to avoid biasing hunter-caused mortality. Differential placement of solar transmitters and metal strap tag(s) served to identify bucks and buck fawns uniquely when at the feeders.

We located deer at least twice each week during the winter, and once or twice per day during November, December, March, and April to determine the timing of migration. We alternated location times throughout the 24-hour day during the year. We used standard telemetry triangulation techniques (Mech 1983) except that azimuths to radio-transmitters were usually taken relative to a reference transmitter in a fixed location rather than relative to magnetic north. Missing or dispersed deer were located with fixed-wing aircraft. Intensive radio-tracking began in October 1986 and ended in July 1989, with monthly locations recorded after that until the transmitters failed or the deer died. We calculated deer locations from bearings using a modified version of the computer program XYLOG (Dodge and Steiner 1986).

In order to classify deer as fed or unfed, and to determine family groups, we closely observed feeders from adjacent houses for 24 consecutive hours once each week, and daily during the peak hours of feeder use (one hour before sunset until 7 hours after, determined from the 24-hour observation periods), from October 1986 until July 1989. We supplemented these observations with 4-hour observation periods at least once each week at randomly determined times of day and night outside the 8-hour interval observed daily. At Long Lake we observed feeding primarily from parked vehicles in 4-hour increments. Since all deer at that location readily used feeders, more extensive observations were unnecessary. We facilitated night observations with mounted floodlights. Deer rapidly acclimated to floodlights. We classified a deer as supplementally fed if we observed it at the feeders at least once per week. In all but two cases, if a tagged deer used the feeder more than once, it used the feeders nightly. We recorded the arrival time and length of stay of each marked and unmarked deer at the feeders. Deer-hours of feeder use were calculated by summing length of time for each deer at the feeders.

We recorded seasonal movements from summer range to winter range, and back again for all deer with non-overlapping seasonal ranges ($n = 108$). Dates were recorded for first departure from summer range to the winter deeryards. We also recorded the first date of arrival of each radio-tagged deer on winter range, the date of first departure from winter range the following spring, and first date of arrival back on summer range. Each year of data per deer was considered independently because many deer changed classification (age or feeding regime) between years. We also performed analysis with each deer represented only in its first year after capture in order to examine the possible effects of non-independent sampling.

We tested the effects of feeding regime, as well as other variables such as sex, age, year, and family group, on the timing of migration of each deer, and each family group using multiple linear regression. We controlled experimental error rates in multiple comparisons between family groups using Scheffe's test. Rates of migration versus not migrating were compared using the binomial distribution (Statistical Analysis System, SAS Institute, Carey, North Carolina).

We estimated survival rates using the method described by Trent and Rongstad (1974) as incorporated in the survival analysis program MICRO-MORT (Heisey and Fuller 1985; Nelson and Mech 1986). Winter survival rates (1 January to 30 April) and summer survival rates (1 May to 31 December) were calculated for each experimental group. We compared interval survival rates with Z-tests (Heisey and Fuller 1985) for the different feeding regimes.

Only deer with working transmitters at the time of death were included in survival analysis to prevent cause-specific bias toward hunting mortality. We could not determine the fates of five deer (i.e., transmitter failed and not subsequently resighted). We assumed all of these deer were alive on the last day that they were located, although it is possible that some or all of them were killed, and the transmitter destroyed. This assumption means survival estimates are a maximum.

We categorized each winter using the Wisconsin Department of Natural Resources index based on cold days and snow depth (Kohn 1978). Each day that had a minimum temperature of <-18 degrees C [0 degrees F] contributed 1 point to the Winter Severity Index (WSI) and each day with snow depth >46 cm [18 inches] contributed 1 point to the WSI. Any day meeting both conditions contributed 2 points to the WSI. The WSI was cumulative over an entire winter. Totals of <50 , $50-80$, >80 were classed as mild, moderate, or severe, respectively.

Results

We trapped and marked 50 adult does, 11 adult bucks, and 54 each of buck and doe fawns. We marked 40 during the first year of the study, and 49 and 80 in the two succeeding years. We observed the feeding areas for 1875 hours distributed over three years. Not surprisingly, deer use of the feeders was greater during a moderate and a severe winter than during a mild winter. The winter of 1986-87 had the least activity with 0.5 deer per hour of observation and a WSI of 7 (all cold days). The winter of 1987-88 had the greatest deer activity with an average 1.4 deer per hour of observation, and had a WSI of 94 (32 cold days). There were 1.0 deer per hour of observation during the winter of 1988-89, which had a WSI of 125 (42 cold days).

The number of deer using the feeders was consistent each year during the study. The total number of different deer using the summer feeders was 21, 23, and 26 for 1986, 1987, and 1988 respectively. This consisted of 6-8 does, 8-12 fawns, and 5-7 adult bucks each year. The number of deer using the winter feeders at Spider Lake was 20 in 1986, and 39 in each of the following two years. This included 8 does, 10 fawns, and 2 bucks in 1987, 15 does, 17 fawns, and 7 bucks in 1988, and 16 does, 19 fawns, and 4 bucks in 1989. Over 200 different deer used the Long Lake feeders.

Most deer did not change their feeding group during the study. Of 37 deer for which we had >1 year of observations and telemetry data, seven changed feeding regimes. Three summer-fed deer stopped using summer feeders in a subsequent year, one winter-fed deer stopped using feeders in a following year, one deer stopped using summer feeders, used no feeders for a year, then used the winter feeders,

and three unfed deer began using feeders after encountering them in a subsequent year.

Migration

Most of the deer (130 of 167) in the study were migratory at least one year during the study. All of 59 deer fed on summer range were migratory. Control deer were more likely to migrate (70%, 33 of 47) than winter-fed deer (42%, 38 of 91) ($Z = 2.378$, $P = 0.0174$). Summer-fed deer migrated later in the autumn than the other deer in the study. No other feeding effects on the timing of migration were noted. The average date of departure from summer range to winter range for both control deer and winter-fed deer was 24 November (± 9.6 and 9.2 days S.E., respectively). The average autumn migration date for summer-fed deer was 15 days later (± 4.2 days S.E.) than other deer ($F = 2.75$; 2, 49 d.f.; $P = 0.074$). Snow fall accumulation did not exceed 25 cm during any November or December during our study. The mean date of departure for the autumn migration was not significantly different among years. Feeding regime had no bearing on distances deer migrated ($P > 0.05$). Migratory deer averaged 15.3 km (± 10.2 km SD) between summer range and winter range.

Feeding regime had no effect on the spring migration departure date from the winter range. However, the severity of the winter did affect when deer migrated in the spring ($F = 110.1$, 2, 57 d.f., $P < 0.0001$). In 1987, both unfed and summer-fed deer averaged a spring departure date of 15 March (± 2 days S.E.) when mean snow depth was 5 cm, and winter-fed deer averaged 22 March (± 8 days S.E.) when 50% of the ground was bare. In 1988, supplementally-fed and control deer all averaged a spring departure of 2 April (± 9 days S.E.) when 10% of ground was bare. In 1989, after the severe winter, each deer group averaged a departure from the deeryards of 12 April (± 4 days S.E.) when mean snow depth was 10 cm, although south slopes were clear of snow.

Survival

Supplemental feeding during the autumn or winter did increase winter survival during the severest winter, but otherwise did not significantly increase deer survival. In fact, summer-fed does had higher hunting mortality than other feeding groups. Supplemental feeding was effective in reducing mortality only during the severe winter of 1988-1989 when control deer had lower average winter (120 day) survival ($\bar{x} = 0.79$, $0.64 - 0.97$ 95% C.I.) than both summer-fed ($\bar{x} = 0.96$, $0.88 - 1.00$ 95% C.I.; $Z = 1.83$, $P = 0.0672$ [above normal 0.05 rejections level]), and winter-fed deer ($\bar{x} = 1.00$, $Z = 2.52$, $P = 0.0118$). All of five mortalities directly due to winter severity were fawns. Winter survival rates did not differ between males and females of the same feeding group, and were thus pooled ($P > 0.10$).

No other survival rates were significantly different ($P > 0.05$), although some differences are worth noting (see Table 1 for confidence intervals). Average annual survival rates were higher for winter-fed deer ($\bar{\chi} = 0.78$) than for summer-fed deer ($\bar{\chi} = 0.53$) and control deer ($\bar{\chi} = 0.64$). Average winter survival was lower for control deer ($\bar{\chi} = 0.85$) than for summer-fed deer ($\bar{\chi} = 0.95$) or winter-fed deer ($\bar{\chi} = 1.00$). Average summer survival rates were 0.76 for both winter-fed deer and control deer. The summer survival rate for summer-fed deer was 0.56.

Legal harvest was the greatest cause of mortality, accounting for 63% ($n = 29$) of all deaths, illegal harvest and unrecovered deer accounted for 11% ($n = 5$), and vehicle collisions accounted for 6% ($n = 3$). Mortality not directly caused by humans accounted for 17% ($n = 8$) of all deer deaths. These included predation by Coyotes (*Canis latrans*) ($n = 3$), breaking through surface ice on lakes ($n = 2$), starvation ($n = 2$), disease ($n = 1$), and unknown causes ($n = 1$). The survival rates of all deer were lower in the summer ($\bar{\chi} = 0.68$), than the winter ($\bar{\chi} = 0.94$), expected since hunting was the primary cause of mortality.

Discussion

Despite a large sample size and inclusion of mild, moderate, and severe winters during the study, population level effects of supplemental feeding were limited to a small but significant increase in winter survival in one winter, a delaying of the autumn migration in summer-fed deer, and associated higher hunting mortality in summer-fed does. These differences do not seem great enough to warrant use of supplemental feeding by government agencies to increase overwinter survival, nor detrimental enough to discourage recreational deer feeders.

We found hunting mortality was higher for does fed on summer range (42% of all mortality) than for winter-fed does (16%) or the control does (8%). This

increase probably resulted from the increased susceptibility to corn baiting by Wisconsin deer hunters during the autumn hunting period, or the increased vulnerability of deer concentrated near summer feeders.

Feeding in either season increased winter survival during the severe winter of 1988-1989. During that winter, winter-fed and summer-fed deer had higher survival than control deer. The 0.20 improvement in winter survival from supplemental food may not be important at such high winter survival rates for unfed deer. However, at lower survival rates caused by longer winters, or successive hard winters, this difference would likely be greater. Furthermore, Mech et al. (1991) found doe survival in the face of wolf predation was directly related to maternal fitness during gestation. In areas with significant wolf populations, survival differences of supplementally fed deer might be greater than in areas without that additional food.

There does not appear to be an optimal season for supplemental feeding to improve winter survival. Verme (1962) suggested that spring nutrition was important to the recovery of deer from winter stress. This formed the basis of Wisconsin DNR's emphasis on summer range management (McCaffery and Creed 1969). However, Dahlberg and Guettinger (1956) and Ozoga and Verme (1982) reported that the welfare of northern deer depended on winter nutritional status. Although the survival value of winter versus summer feeding can not be readily distinguished from our survival data, in each spring, including the one following the mild winter of 1986-1987, winter-fed deer appeared qualitatively better (larger, fatter) than summer-fed deer at the beginning of spring. During more protracted winters, this difference might become important as well.

Most White-Tailed Deer at the northern extent of their range seasonally migrate from summer range to a separate winter range (Carlsen and Farnes 1957; Hoskinson and Mech 1976; Rongstad and Tester 1969; Tierson et al. 1985; Verme 1973). Kufeld et al.

TABLE 1. Annual and seasonal survival rates of White-Tailed Deer in northern Wisconsin.

	Summer (245) ^a			Winter (120) ^a			Annual (365) ^b	
	(1 May – 31 Dec)			(1 Jan – 30 April)				
	Rate	95% C.I.	N ^b	Rate	95% C.I.	N ^b	Rate	95% C.I.
Control	0.76	0.60-0.97	4574	0.85	0.76-0.98	3678	0.64	0.49-0.84
Winter-fed	0.76	0.64-0.90	8780	1.00	1.00-1.00	5992	0.78	0.67-0.91
Summer-fed	0.56	0.42-0.74	6721	0.95	0.88-1.00	4823	0.53	0.39-0.71
Control males	0.52	0.27-0.98	1492	0.80	0.59-1.00	1086	0.43	0.21-0.84
Control females	0.92	0.79-1.00	3082	0.87	0.74-1.00	2592	0.77	0.60-0.99
Summer-fed males	0.49	0.26-0.91	1736	1.00	1.00-1.00	1716	0.44	0.22-0.90
Summer-fed females	0.58	0.42-0.80	4985	0.92	0.83-1.00	3107	0.55	0.40-0.76
Winter-fed males	0.47	0.24-0.91	1623	1.00	1.00-1.00	1089	0.51	0.28-0.92
Winter-fed females	0.84	0.72-0.98	7157	1.00	1.00-1.00	4903	0.86	0.75-0.98

^aTotal days in interval.

^bRadiotransmitter days.

(1989) suggested that year-round residency resulted from a habitat of high quality in all seasons. Variable habitat quality did not seem to explain the migratory behavior in our study, although supplemental foods certainly increased food available on both summer and winter ranges. Nelson and Mech (1987) described the importance of genetically related groups acting together, which was consistent with the importance of family group in the timing and direction of migration that we found.

Unlike emergency feeding, which heavily concentrates deer and may even kill them if improperly applied (Woolf and Kradel 1977; Wobeser and Runge 1975; Carhart 1943), recreational feeding seems to do little direct harm, and does increase winter survival during severe winters. However, the marginal increases in winter survival could be far more cheaply obtained by reducing doe harvests the following hunting season. This would make deer feeding far too expensive for broad-spread management use, but perhaps useful in an educational setting that increase awareness of wildlife such as a nature or visitor center. In addition, some botanists (e.g., Alverson et al. 1988) have raised concerns about the impacts of increased deer herds on native forbs and woody plants.

We found a definite increase in deer winter survival from the *ad libitum* supplements. However, 63% of all deer mortalities in our study were due to legal harvest, while just 13% were winter related. Except in extremely severe winters, regulating harvest would be a more effective means of regulating herd size, and regular supplemental feeding probably should not be attempted by management agencies. Cost effectiveness for public agencies for feeding all winter has not been evaluated, although Lenarz (1991) found emergency feeding late in the winter could not be justified by cost. Given the limited survival effects, its use by the public is probably irrelevant from a management point of view during most years. During severe winters, feeding by the public would lower the costs of distribution, making it more likely that supplemental feeding could be cost effective.

Feeders do not seem to draw deer from very far. No doe traveled > 2.5 km on a regular basis to reach the feeders, and only one tagged deer moved more than this to reach the feeders after the winter became severe. This would suggest the need to disperse feeders widely to reach a higher percent of the deer herd and reduce aggression at feeders, much as is found when the general public feeds wildlife.

Summer supplemental feeding increased deer vulnerability to hunting. One potential explanation is that summer feeding increased the likelihood of deer visiting bait stations using corn as bait. This needs to be considered in states where hunting over bait is permitted. This was further complicated in our study by the delay of autumn migration caused by feeding. Summer-fed deer often migrated during or after the

deer-gun season, leaving them more vulnerable to hunting than deer already on their winter range. This, rather than susceptibility to baiting, may explain the higher hunting mortality of summer-fed deer.

Perhaps the only unique benefit of supplemental feeding is the increased public awareness and interest in wildlife and wildlife management at no cost to the public. People who feed deer become very interested and active in deer management, and in the other wildlife that visit their feeders. This educational benefit would certainly supplement the many fine educational programs at nature and information centers, and is hardly different from the use of food plots to draw animals into viewing range, including economically (McBryde 1995). This educational benefit, rather than increased survival of deer, may be the real value of recreational feeding. Gerstell (1942: 109) states, "Through the interest in birds and mammals which is so created [by feeding], it is possible to develop in the minds of many persons a desire for greater knowledge of wildlife and the out-of-doors. This is the foundation upon which active cooperation in general conservation programs must be built. *Its value cannot be over-estimated*" (his emphasis).

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Predictive Relationships Between Age and Size and Front-foot Pad Width of Northeastern Minnesota Black Bears, *Ursus americanus*

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Front-foot pad width, age, body length, weight, and skull width were measured on 139 Black Bears (*Ursus americanus*) from northeastern Minnesota. We developed regression models using these data to predict body length, weight, and skull width from pad width measurements.

Key Words: Black Bears, *Ursus americanus*, pad width, body length, weight, skull width.

Foot prints or tracks are a common sign of the occurrence of a wildlife species. By understanding the relationship between foot size and other physical dimensions of an individual animal, researchers and managers may be able to remotely and inexpensively extract useful information on the size and age distribution of a population from animal tracks (Piekielek and Burton 1975; Beck 1991), especially if tracks could be taken under controlled conditions (Zielinski 1995). We examined the relationships between front-foot pad width and age and physical dimensions of Black Bears, *Ursus americanus*, from northeastern Minnesota to investigate the potential use of track dimensions for the prediction of these attributes.

Methods

Data were collected from bears in the Superior National Forest, northeastern Minnesota. The study area and capture methods were fully described by Rogers (1987). Each captured bear was sexed and weighed. The front-foot pad was measured across its greatest width, taking care to flatten the pad to approximate its shape when bearing weight. Maximum pad width was measured between the hairlines at the edges of the pad. Total body length was measured along the contour of the back, from the tip of the nosepad to the tip of the bone in the tail, taking care to position the muzzle, head, back, and tail in as straight a line as possible. Skull width was measured at the zygomatic arches, including skin and any fat, using calipers. Length and width measurements were taken to the nearest 0.0625-inch and converted to metric units for analysis and reporting. Bears were uniquely marked with eartags when first captured and remeasured upon recapture.

Year of birth was determined by cementum annuli from a first upper premolar (Willey 1974). We cal-

culated a measure of continuous age as the age, in years at the time of capture, plus a decimal value accounting for the time between 1 January (presumed date of birth) and the date of capture. Bears were classified as: (1) cubs: < 1.0 year old; (2) yearlings: 1.0–1.9 years; (3) subadults: 2–3.9 years; and (4) adults: ≥ 4.0 years (Rogers 1987).

The predictive relationships between continuous age and other physical dimensions and pad width were examined using linear and nonlinear regression models. Regressions were run separately for each sex and for the combined sexes. We evaluated linear, linear with \log_e - \log_e transformation, and nonlinear regression models. We selected a simple linear model of the transformed data, corresponding to $E(y) = b_0(x)^{b_1}$ for measured data, based on regression statistics and plots of residuals, as the best model for all regression analyses. Confidence intervals on estimates from a single additional observation were calculated following Zar (1974: 211–212; equation 16.27). Analysis of variance was used to explore the relationship between pad width and ageclass. Classification intervals for ageclass based on a new observation of pad width were calculated using Sokal and Rohlf's (1981) single-sample comparison and appropriate sample statistics.

To use all the data, and yet avoid the repeated-measures nature of the multiple observations, we used the mean of all measurements of each variable for each bear as a single data point. We then weighted these data points in the analyses by the number of observations included in each mean. Because the multiple measurements of pad width and the response variables for each individual bear were taken over a relatively short interval of a few years and the relationships were essentially linear, this procedure did not bias the analyses.

Results and Discussion

Two hundred eleven measurements of age, foot-pad widths, and other physical dimensions were obtained from 139 Black Bears in northeastern Minnesota between 1969–1982. Some measurements were missing for some bears, so sample sizes vary among analyses.

Regression models between Black Bear continuous age, body length, weight, and skull width and pad width were significant ($p < 0.001$) for both sexes individually and combined (Table 1). The adjusted r^2 for the regressions ranged between 0.363 to 0.915. Pad width differed significantly by ageclass ($F = 136.8$, d.f. = 3, 195, $p < 0.001$).

We identified two general quantitative relationships between the four individual independent variables and pad width. The constant (b_0) for the relationship between continuous age and pad width and weight and pad width was close to zero with a power coefficient (b_1) of about 3. These models described a steeply ascending curve where small increases in pad width result in increasingly greater gains in age or weight with larger pad widths. This result was similar to that of Piekielek and Burton (1975) who reported a power coefficient of 3.5 for the relationship between Black Bear weight and a six-part composite foot measurement. The relationships between body length and pad width and skull width and pad width were essentially linear as the power coefficients were close to one. Body length and skull width increased at a constant rate with increasing pad width.

The models developed from these data allow for the estimation of body length, weight, and skull width from pad widths (Table 2). If the sex of a new observation is known, the appropriate single-sex model or tabular entry can be used for estimation. If sex is unknown, the combined sex models or tabular entries should be used.

The use of the regression models for estimation of continuous age from pad width was inappropriate because of their poor fit, which resulted in excessively large confidence intervals on the estimates. The classification of ageclass for a new observation of pad width could not be made at 95% confidence because of extensive overlap of classification intervals for all ageclasses. The classification intervals for ageclass at 75% confidence were: cubs < 7.65 cm; yearlings 7.38–9.02 cm; subadults 8.37–10.54 cm; and adults > 9.15 cm. These results allow for the age classification of many tracks with an intermediate degree of certainty but there is still considerable overlap between intervals where classification is uncertain.

The results from this study suggest that further investigation of the relationship among Black Bear pad width, foot-print width, and physical dimensions is warranted. The application of these prediction models in the field, that is to front-foot prints, introduces additional variability related to the relationship between pad width and foot-print width, which is not accounted for in this study (Beck 1991). Piekielek and Burton (1975) found the composite foot measurements taken from tracks were

TABLE 1. Regression statistics¹ from the analysis of pad width and continuous age, body length, weight, and skull width by sex and for both sexes combined for Black Bears from northeastern Minnesota, 1969–1982.

Dependent variable	n measurements/ n bears	b_0	b_1	Adjusted r^2	F
Continuous age					
Males	88/68	0.001	3.502	0.805	359.4
Females	115/69	3.8×10^{-6}	6.404	0.581	158.8
Combined	203/137	0.005	2.947	0.363	116.3
Body length					
Males	90/71	10.4	1.103	0.869	590.8
Females	111/66	5.795	1.411	0.771	371.5
Combined	201/137	12.9	1.03	0.771	675.2
Weight					
Males	91/71	0.013	3.645	0.915	966.0
Females	113/68	0.007	4.101	0.789	421.1
Combined	204/139	0.037	3.253	0.806	843.7
Skull width					
Males	85/66	1.39	1.043	0.858	508.4
Females	104/61	1.63	1.0	0.677	217.3
Combined	189/127	1.79	0.944	0.792	719.0

¹for the general model: $E(Y) = b_0 + (pad\ width)^{b_1}$

TABLE 2. Estimated body length, weight, and skull width (with a 95% confidence interval in parentheses) by sex and for both sexes combined from regression models (from Table 2) of Black Bear pad width, northeastern Minnesota, 1969-1982.

Pad width classes	Estimated								
	Body length			Weight			Skull width		
	Males	Females	Combined	Males	Females	Combined	Males	Females	Combined
-cm-									
5	61.6 (56.6- 67.0)		67.6 (61.9- 73.8)	4.6 (3.0- 7.1)		7.0 (4.9- 10.1)	7.4 (6.3- 8.8)		8.2 (7.6- 8.9)
6	75.3 (64.0- 88.5)	72.6 (63.4- 83.1)	81.6 (74.9- 88.9)	8.9 (5.9- 13.5)	10.3 (6.9- 15.3)	12.7 (9.0- 18.0)	9.0 (7.6- 10.6)	9.8 (8.5- 11.2)	9.7 (9.0- 10.5)
7	89.2 (76.2- 104.6)	90.3 (79.3- 102.7)	95.6 (87.8- 104.1)	15.6 (10.4- 23.5)	19.4 (13.2- 28.4)	21.0 (15.1- 29.4)	10.5 (9.0- 12.4)	11.4 (10.0- 13.0)	11.3 (10.4- 12.2)
8	103.4 (88.4- 120.9)	109.0 (96.0- 123.7)	109.7 (100.9- 119.3)	25.4 (17.0- 38.1)	33.5 (23.0- 48.7)	32.5 (23.5- 44.9)	12.1 (10.4- 14.2)	13.0 (11.5- 14.8)	12.8 (11.8- 13.8)
9	117.7 (100.8- 137.5)	128.7 (113.4- 145.9)	123.9 (113.9- 134.7)	39.1 (26.2- 58.3)	54.3 (37.4- 78.7)	47.6 (34.7- 65.3)	13.7 (11.7- 16.0)	14.6 (12.9- 16.6)	14.3 (13.2- 15.4)
10	132.3 (113.3- 154.4)	149.3 (131.5- 169.5)	138.1 (126.9- 150.1)	57.3 (38.5- 85.5)	83.6 (57.5- 121.6)	67.1 (49.3- 91.4)	15.3 (13.1- 17.9)	16.3 (14.3- 18.5)	15.8 (14.6- 17.1)
11	146.9 (125.8- 171.5)		152.3 (140.0- 165.7)	81.2 (54.4- 121.0)		91.5 (67.6- 123.8)	16.9 (14.5- 19.7)		17.3 (16.0- 18.7)
12	161.7 (138.4- 188.9)		166.6 (153.1- 181.2)	111.4 (74.6- 166.4)		121.4 (90.2- 163.5)	18.5 (15.8- 21.6)		18.7 (17.3- 20.3)

about 10% less than the true value obtained from the animal.

Track measurements from designed surveys, possibly using scent stations (Lindzey et al. 1977) with track plates (Zielinski 1995) or other media (Wemmer et al. 1996), and combined with camera systems (Jones and Raphael 1993) and/or DNA fingerprinting (Woods et al. 1996) could provide useful and inexpensive information about a Black Bear population. By controlling for substrate and gait conditions, extraneous foot-print variability should be reduced. Additional measurement and analyses of sex, age, pad width, and other physical dimensions and of foot-print width would create a data and knowledge base to increase the information available from standardized track surveys.

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Lead Shot Ingestion in Several Species of Birds in the Western James Bay Region of Northern Ontario

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Lead shot exposure in several bird species harvested by First Nation Cree in the western James Bay region of northern Ontario, Canada was determined by manual examination of gizzard contents and by radiography. A total of 568 gizzards was examined. Upland gamebirds and shorebirds sampled were not found to have ingested shot. Ingestion of lead shot by ducks and geese harvested in the spring (3.0% and 5.2%, respectively) and fall (4.2% and 4.0%, respectively), indicate lead shot exposure occurs in waterfowl in the western James Bay region.

Key Words: Birds, First Nations, James Bay, lead shot exposure.

In the United States and the Netherlands, the use of lead shot for waterfowl hunting is banned owing to the deleterious effect of lead on waterfowl (United States Fish and Wildlife Service [USFWS] 1988, Annema et al. 1993). Only a limited number of “non-toxic” zones, where the use of lead shot is prohibited, currently exist in Canada (DeStefano et al. 1991; Daury et al. 1994; Scheuhammer and Norris 1995). However, Canadian officials intend to ban lead shot for migratory bird hunting nation-wide beginning in the fall of 1999. Until then, lead shot still will be widely used by sport and native Canadian hunters. Hunter compliance to the new non-toxic regulations may be limited in Ontario because current information “indicates that lead poisoning has limited occurrence in Ontario ... additional sampling may be required in some areas” to prove that lead poisoning is a problem in this region (Dennis 1993: 65). One area where information on avian exposure to lead shot is lacking is the western James Bay region of northern Ontario.

In Canada, an estimated 2000 metric tonnes of lead shot is discharged into the environment each year (Scheuhammer and Norris 1995). In the western James Bay region of northern Ontario, an estimated 34 metric tonnes of lead pellets are deposited annually (Tsuji et al. 1996). Most waterfowl hunting in the fall is concentrated along the coast and in the spring along the coast and waterways of the western James Bay region (Berkes et al. 1995). Therefore, large numbers of lead pellets are deposited into the wetlands of the region and may be a source of lead for birds migrating and breeding in the area.

There is growing concern among First Nations of the region that the lead shot used in subsistence hunting may be adversely affecting the environment and wildlife of the region. Growing concern can be

attributed to personal observations by native people of decreasing numbers of Canada Geese and scientific data contained in the Bortner et al. (1991) study. Bortner et al. (1991) reported decreasing numbers of Canada Geese in the region and have related this to poor productivity. This decrease may be in part lead related as lead has been shown to affect reproduction in birds (e.g., Stone and Soares 1976). In the present study, we take the first step in determining whether lead poisoning may pose a potential problem for birds inhabiting or migrating through the western James Bay region, by examining if birds are actually exposed to lead through ingesting of lead shot.

Study Area

The James Bay region of northern Ontario, Canada is a dynamic ecosystem of wetlands and muskeg (Thomas and Prevett 1982; described in detail by Hanson 1953) which is currently undergoing post-glacial isostatic rebound (Mitrovica et al. 1994). Western James Bay is a major migratory staging, breeding and moulting area to a multitude of waterfowl (Thomas and Prevett 1982), shorebirds (Godfrey 1986) and home to several species of upland gamebirds. Recently, the Canadian Arctic Resources Committee identified this area as a “hotspot” of high biodiversity and productivity, requiring protection (Beckmann 1994).

Methods

Gizzard samples were obtained in the area delineated by the latitudes, 52°N - 53°N, and the longitudes, 81°W - 82°W, in the vicinity of Fort Albany. Gizzards were recovered from waterbirds harvested by First Nation hunters in the western James Bay region during the spring (April-May, 1994-1996) and fall (August-October, 1994-1995) hunts.

Gizzards from upland gamebirds were salvaged during the period 1990-1996. All gizzards were either collected fresh or were labelled and frozen by the hunters until collected by the researchers.

Following the procedure described by Schwab and Daury (1989: 238), all gizzards were incised (frozen gizzards were thawed first) to allow for the emptying of gizzard contents into a white-coloured bowl. Gizzard contents (containing grit) were washed with flowing water to remove vegetation through flotation. Remaining sediments (grit) were then examined manually for shot and/or fragments. Shot and fragments were tested for composition (steel versus lead) using either a magnet and/or the cutting of the shot with a scalpel. All pellets within the gizzard cavity that exhibited "shot facets" with an entry wound being present in the gizzard wall were eliminated because these pellets were shot in and not ingested by the bird.

Grit samples from each gizzard were then placed in the bottom portion of a 60 × 15 mm clear plastic petri dish. Petri dishes, each on a single Kodak Ultra Speed (size 4) occlusal film, were placed under the tube of a Siemens Heliodont 70, radiographic unit. The grit/film was then radiographed (70 Kv, 7 ma, 18 msec) and the film processed. Any grit sample with a corresponding radiograph exhibiting a lead signature was subsequently examined for lead shot, using the criterion described earlier. The use of radiographs has been shown by numerous researchers (e.g., Anderson and Havera 1985, Montalbano and Hines 1986) to increase the accuracy of detecting ingested lead pellets by at least 20% compared to manual/visual examination alone.

A total of 568 gizzards was examined, and grit samples were divided into six categories: grouse [Spruce Grouse (*Dendragapus canadensis*) and Sharp-tailed Grouse (*Tympanuchus phasianellus*)]; shorebirds [Hudsonian Gull (*Limosa haemastica*) and Common Snipe (*Gallinago gallinago*)]; ducks - spring [Mallard (*Anas platyrhynchos*), Northern Pintail (*A. acuta*) and American Black (*A. rubripes*)]; ducks - fall [Mallard, Northern Pintail and Green-winged Teal (*A. crecca*)]; geese - spring [Snow Goose (*Chen caerulescens*) and Canada Goose (*Branta canadensis*)]; geese - fall [Snow Goose and Canada Goose]. Grouse were not separated into spring and fall samples because these birds are generally non-migratory. Shorebirds were collected only during the fall migration. The other categories were divided into spring and fall classification because the availability of lead shot may differ between seasons. As lead shot ingestion can be roughly assumed to be very recent (i.e., hours to several days), we assume that the lead shot ingestion probably occurred in the study area.

Draft policy of the Canadian Wildlife Service suggests two levels of concern with respect to lead shot ingestion rates for waterfowl: > 5%, further study

required, and > 10%, establishment of a nontoxic zone (Canadian Wildlife Service 1990). In the United States, the 5% lead shot ingestion rate was identified as the level of concern (United States Department of the Interior 1986) prior to the nation-wide ban of lead shot for waterfowl hunting in 1991. In the present study, frequencies of lead ingestion for species found to have ingested lead were tested against an expected lead ingestion rate of 5% (lower level of concern) using Chi-square goodness-of-fit-tests.

Results

Percent of individuals ingesting lead shot, from this study, are given in Table 1. No individual bird had more than one ingested lead pellet. There were no ingested lead pellets present in grouse and shorebirds examined. The percentage of individuals ingesting lead shot are as follows: grouse, 0%; shorebirds, 0%; ducks (spring), 3.0%; ducks (fall), 4.2%; geese (spring), 5.2%; geese (fall), 4.0%.

In all instances of species found to contain lead pellets and/or fragments, the frequency of lead ingestion was not significantly different from an expected frequency of 5% ($\chi^2 < 0.7427$, $df=1$, $P > 0.05$). Thus, all species that ingested lead shot did so at a frequency that warrants concern.

Discussion

The results of this study confirmed local lead shot ingestion in ducks and geese harvested in the western James Bay region. A 5% level of lead shot ingestion, which has been established in the USA as the lower limit of concern for birds, was found in all species that contained lead in this study. However, upland gamebirds and the small sample of shorebirds of the region do not appear to ingest lead shot. In the case of the Sharp-tailed Grouse, only one piece of grit was found in all the gizzards examined. The fact that Sharp-tailed Grouse often use *Rosa* seeds as grit (Schmidt 1936) helps to explain this observation.

Although this study revealed lead exposure through lead pellet ingestion by birds harvested in Canada, it does not address actual lead uptake and intoxication in individual birds. Field observations near Fort Albany during the 1993 hunting season suggested that lead intoxication may have been present in approximately 5% of the Canada Geese observed there with a loss in body condition and/or green staining of the vent area (J. Young, personal observation). Further, two Snow Geese showed unusual behaviour in not exhibiting an evasive response when the rest of the flock was flushed by hunters (J. Young, personal observation). Moreover, necroscopy of a Canada Goose harvested in the spring of 1996 showed loss of body condition with a prominent keel as well as sloughing of the gizzard wall (a lead pellet was also present in the gizzard). These symptoms have often been associated with

TABLE 1. Descriptive data detailing lead shot ingestion in birds harvested during the spring (1994–1996) and fall (1994–1995) hunts in the western James Bay region of northern Ontario, Canada. Data for Sharp-tailed Grouse were collected during 1990–1996. Pb represents the number of birds with lead shot in their gizzards, N the total number examined.

	Spring	Fall
	Pb/N (%)	Pb/N (%)
Grouse		
Spruce	—	0/6 (0)
Sharp-tailed	0/118 (0)	—
Shorebirds		
Snipe	—	0/4 (0)
Godwit	—	0/9 (0)
Ducks		
Mallard	2/69 (3.0)	1/17 (5.9)
Pintail	1/27 (3.7)	0/9 (0)
Black	0/2 (0)	—
Teal	0/1 (0)	1/21 (4.8)
Geese		
Snow	0/25 (0)	3/97 (3.1)
Canada	7/109 (6.4)	3/54 (5.6)

lead poisoning in waterfowl (Friend 1987). However, other diseases may also have played a role in the loss of body condition.

Although lead shot ingestion occurs in waterfowl of the western James Bay region, further data are required to document actual lead uptake by birds (e.g., blood-lead levels, enzyme levels, or liver-lead levels; Friend 1985). With these additional data, the true extent of lead poisoning in waterfowl while in this region of Canada can be established. Once more definitive data are gathered, sport and First Nation hunters of the western James Bay region will have a rational basis for discontinuing the use of lead shot for hunting migratory birds. It should be stressed that compliance with the new non-toxic regulations may be low and enforcement extremely difficult in these remote regions of northern Ontario and the rest of Canada. Thus, lead shot may still be widely used by sport and native subsistence hunters until research demonstrates that use of lead pellets for hunting *in Canada* poses a threat to the environment, wildlife, or human health.

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Walruses, *Odobenus rosmarus*, in the Gulf and Estuary of the St Lawrence, 1992–1996

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The great abundance of Walruses (*Odobenus rosmarus*) in the Gulf of St. Lawrence was documented by the earliest explorers and settlers. The species was reduced and eventually extirpated by exploitation. Occasional sightings have been reported from the eastern part of the north shore of the Gulf over the last century, but none from the central or southern Gulf. This article reports three sightings of Walruses from the central and southern Gulf and the lower estuary in the early 1990s.

Key Words: Walrus, *Odobenus rosmarus*, distribution, Gulf of St Lawrence, Québec.

The habitat of the Walrus (*Odobenus rosmarus*) may be summarised as islands, loose ice and shallow seas. The species hauls out seasonally on ice or on land, but different age and sex classes may show different preferences; populations are normally associated with land haul-outs (but see Reeves 1978, page 14), but inhabit areas of at least seasonal sea-ice cover. The Walrus does not maintain holes in fast ice, so in winter it is restricted to loose ice and natural openings. It is an obligate bottom feeder, specialising in bivalve mollusc in-benthos, and is usually considered to be in consequence somewhat restricted to shallow (<70m to <100m) water, although there is uncertainty about where a limit might lie.

It is well documented that there were lots of Walruses in eastern Canada, south of Arctic latitudes, in earliest historic times; explorers' accounts, and chronicles of life in the communities of the Gulf of St Lawrence, make frequent mention of them, variously as "sea cows", "sea horses", or "hippopotamuses". However varied the names, descriptions that focus on large size, prominent tusks, and crowded haul-outs lead to few errors. The most southerly breeding population in early historic times was on Sable Island, off the east coast of Nova Scotia (Allen 1880; Allen 1972). Haul-out sites mentioned in the Gulf of St Lawrence are Sept-Îles in the north-west Gulf (Lescarbot 1907–1914), Miscou Island in the western Gulf (Perley 1852; Ganong 1904; Gilpin 1870) and several sites on and around the Magdalen Islands in the central Gulf, including Brion Island, Deadman Island, and Entry Island (St-Cyr 1886; Gilpin 1870; Grenfell 1910; Vigneau 1969; Hubert 1979). Within the St Lawrence system, the pristine distribution extended as far upstream as Rivière-Ouelle (47°26' N, 70°01' W) (St-Cyr 1886).

Early settlers found Walruses easy to kill and rewarding to exploit, principally for oil and hides. The abundance of Walruses was one of the attractions of the Magdalen Islands for early settlers (Vigneau 1969). Haul-out sites were exploited to exhaustion (Grenfell 1910): in the 17th century, the English were taking Walruses on Sable Island (Charlevoix 1744) and the French at Miscou (Perley 1852), but the peak of exploitation in the Magdalen Islands was in the second half of the 18th century. Large kills are documented there in that period; Walruses were still plentiful in 1750 (Grenfell 1910) and in 1773 (Gilpin 1870), but the last one was supposedly killed on the islands in 1799 (Vigneau 1969; Hubert 1979). There were occasional sightings in the Magdalen Islands throughout the 19th century (St-Cyr 1886), but none have been recorded in the scientific literature for the central and southern Gulf since the start of the 20th century.

Recent sightings

This article places on record three sightings of Walruses in the central and southern Gulf and the lower estuary of the St Lawrence (Figure 1) in the early 1990s, as follows:

19 October 1992.

On 19 October 1992 a vessel of the Canadian Department of Fisheries and Oceans (DFO) returning from a research mission was travelling west along the north shore of the Gaspé peninsula. Off Ste-Anne-des-Monts, in calm water, but in good light, at the end of the afternoon, the captain saw a large, dark, marine mammal, up-ended in the water to watch the approaching boat. He identified it as a Walrus, on the basis of its size and the general configuration of the head. He had seen Walruses before only on television, he did not see tusks (although he did see something white near the head), the closest

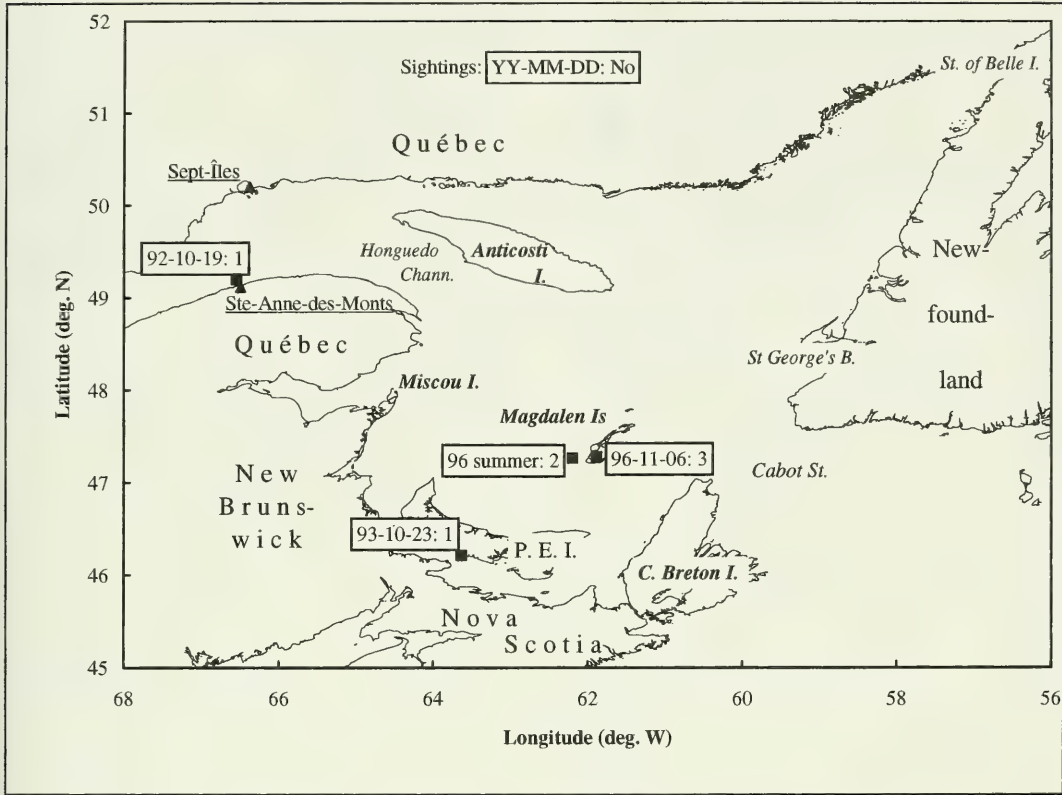


FIGURE 1. The Gulf of St Lawrence, with Walrus sightings reported in 1992, 1993 and 1996.

approach was estimated at about half a mile, and he was the only person on the boat to see it: other members of the crew were below. However, he is an experienced seaman, used to working at sea with scientists, and (like most local seamen) knows seals well. He is confident that it was a Walrus, and was not a seal.

23 October 1993.

A field crew working on environmental baseline studies for the “fixed link” to Prince Edward Island saw a Walrus near Borden, Prince Edward Island (46°13'36" N, 63°38'01" W), close enough (30 m distance) and with enough detail to be confident of the identity. One of the observers had Arctic experience and had seen Walruses in the Arctic “at similar distances and conditions”; he saw tusks and whiskers on this animal (J. L. Barnes, letter to Canadian Department of Fisheries and Oceans, 2 November 1993; Jacques Whitford Environment Ltd 1994).

Summer and Fall 1996.

Three fishermen working crab pots at Havre-aux-Basques, Magdalen Islands, Québec, saw three ani-

mals on the Baie des Plaisances (about 47°17' N, 61°53' W) on or about 6 November. They identified them as Walruses, listing as identifying marks large size (estimated by sight at 1500 lbs), brown colour, wide head, and “neck-less” appearance (DFO. 1996. Rapport d’entrevue du vendredi 22 novembre 1996. File note, Canadian Department of Fisheries and Oceans, Cap-aux-Meules, Québec. 1 page); they also saw tusks on one of the animals (Hubert 1996a). This sighting was reported to the Department of Fisheries and Oceans in Cap-aux-Meules, Magdalen Islands.

Subsequent to a newspaper report of this observation, it transpired that a diver had, earlier that year, seen and identified two Walruses near Deadman’s Island (47°16' N, 62°12' W) which is off the southwestern point of the Magdalen Islands (Hubert 1996b); this sighting was reported to the Canadian Coast Guard when it was made. These two observations are considered to be of the same group.

Discussion

The second and third of these sightings appear to be absolutely reliable, although no photographs or

collections were available. The 1993 sighting was made by a marine environmental science team of four, and included in their formal report. The November 1996 sighting was made by three experienced fishermen, under good conditions, and is confirmed by the summer sighting that was very close to it. The 1992 sighting is the least well confirmed, as only one person saw the animal and not from very close to. I would not consider it reportable if the other two had not been made in the succeeding years.

The most recent review of extra-limital sightings of Walruses on the Canadian east coast is by Mercer (1967), who presented five recent sightings in eastern Newfoundland. He reviewed records collected in the early 20th century from the northern Gulf by Lewis and Douth (1942)—their record in December about 1910 may be that reported by Vigneau (1908)—as well as sightings or collections in the late 19th century in the Strait of Belle Isle (Gilpin 1870), and in St. George's Bay in south-western Newfoundland (Reeks 1871). Walruses are seen on the coasts of Newfoundland from time to time; there have been about three sightings in southern and southeastern Newfoundland in the early 1990s (DFO Marine Mammal Section, St. John's, Newfoundland, unpublished data). However, Mercer cited no reports from the central or southern Gulf, although it is excellent habitat for Walruses: it is seasonally covered with ice, which in the southern and western Gulf consolidates, but to the north and east of the Magdalen Islands is kept open by the south-east-setting current and the persistent north-westerly winds. The water is uniformly shallow, with generally sandy bottoms that give good production of the Walrus's preferred foods.

The 1996 sightings in the Magdalen Islands were publicised in the local media. In spite of that, no local inhabitants reported any other earlier sightings, previously unreported because of lack of interest or not knowing whom to send such reports to. This still doesn't guarantee that there have been no sightings by fishermen or others, but perhaps makes it less likely.

Mercer (1967) noted that all sightings of known sex were of males. No sex information is available for the recent sightings in the Gulf. There has been no reason to suppose that occasional sightings represented a tendency for the species to recolonise its former habitat; but the practice of shooting Walruses when they were seen [e.g. in 1869 (Gilpin 1870); in 1937 (Wright 1951); in 1949 (Mercer 1967)] would in any case have deterred them. The Marine Mammal Regulations made under the Fisheries Act, as well as the prevailing ethos regarding marine mammals, now discountenance such actions; what effect this may have on the fre-

quency of sightings or the distribution of the species remains to be seen.

Acknowledgments

I thank the people with whom these observations originated for the interest that prompted them to record the sightings and send them in, for their willingness to answer questions about them and to allow them to be used in this article. I thank R. Simon and the DFO staff at Cap-aux-Meules for their help in following up the 1996 sightings on the Magdalen Islands.

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Rare and Endangered Fishes and Marine Mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports: XII

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Campbell, R. R. *Editor*. 1998. Rare and endangered fishes and marine mammals of Canada: COSEWIC Fish and Marine Mammal Subcommittee Status Reports XII. *Canadian Field-Naturalist* 112(1): 94–97.

Eight status reports representing the 1997 fish and marine mammal status assignments have been prepared for publication. Committee (COSEWIC) and Subcommittee (Fish and Marine Mammals) activities are briefly discussed.

Huit rapports de statut relativement aux poissons et aux mammifères marins auquel ont été attribués un statut en 1997 ont été préparés pour publication. Les activités du Comité (CSEMDC) et du sous-comité (des poissons et des mammifères marins) sont brièvement discutées.

Key Words: Rare and Endangered species, fish, marine mammals, COSEWIC, Canada.

As indicated in previous submissions (Campbell 1984 through 1997), the intent of the Subcommittee on Fish and Marine Mammals is to publish the status reports (on those species of fish and marine mammals) which the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) has reviewed, approved and used as a basis of assigning status to species in jeopardy in Canada. The group of eight reports presented herein represent the fish and marine mammal component of those species assigned status in 1997 (*see* COSEWIC 1997). It is hoped that we will be able to find continuing financial support to offer, in succeeding volumes, those reports reviewed in future years.

Progress

COSEWIC has undertaken to make available to all Canadians supporting information on each species classified (*see* Cook and Muir 1984). The Fish and Marine Mammal Subcommittee has been able to use this journal as one step in achieving the goal. A series of reports have appeared in various volumes and numbers from 1984 through 1996 [*see The Canadian Field-Naturalist* 98(1): 63–133; 99(3): 404–450; 101(2): 165–309; 102(1): 81–176 and 102(2): 270–398; 103(2): 147–220; 104(1): 1–145; 105(2): 151–250; 106(1): 1–72; 107(4): 395–546; 110(3): 454–532; 111(2): 249–307].

As of April 1997, COSEWIC has reviewed the status of 92 fish species, two marine invertebrates, and 42 marine mammals (*see* Campbell 1997: Table 1; COSEWIC 1997). Of the 149 species (or discrete populations) investigated nine are indeterminate (seven fish, two marine mammals), 59 (26 fish, 32 marine mammals, one marine invertebrate) have been found not to require status designation and another 46 (40 fish, six marine mammals) have been

designated as vulnerable, mainly due to natural rarity; leaving 25 species (16 fish, nine marine mammals) of immediate concern (threatened and endangered), and 10 species (six fish, three marine mammals, and one marine mollusc) extinct or extirpated.

There are currently 48 status reports on fish species (including 23 updates), one on a marine mollusc (update), and 10 on marine mammal species (three updates) under review or in preparation (Table 1). Several of these will be presented to the Committee for status assignment in 1998.

As well, some 84 additional species of fish (plus seven to be updated), two marine mammal updates, and 12 marine invertebrates have been identified as being worthy of consideration (Table 2; and Campbell 1997: Table 3). Many may be found to not require status designation, but the process serves to bring together the information necessary to make the appropriate determination and satisfy the need to fill those knowledge gaps. Although some of these may be of no immediate concern, the Subcommittee will, as opportunity allows, attempt to document the status of these species to determine their status in Canada.

In addition to soliciting further status reports on species of concern, the Subcommittee continues to obtain updates on the status of selected species as new information becomes available, or in the 10 year review process initiated in 1993 (Table 2; and Campbell 1997: Table 3) for those species which had not already received further examination following the initial assignment of status.

Concluding Remarks

The eight reports included in the following series are reports on the status of the respective species in Canada. Status was assigned by consensus of the COSEWIC Committee based on these reports which

TABLE 1. Fish and Marine Mammal Species for which Status Reports are in preparation, or under review - to 17 April 1997.

Species	Scientific Name	Proposed Status
FISH		
Chestnut Lamprey ^o	<i>Ichthyomyzon castaneus</i>	Vulnerable April 1991
Lake Lamprey ^o	<i>Lampeta macrostoma</i>	Vulnerable April 1986
Basking Shark	<i>Ceterohinus maximus</i>	?
Shortnose Sturgeon ^o	<i>Acipenser brevirostrum</i>	Vulnerable April 1980
Atlantic Sturgeon	<i>Acipenser oxyrhynchus</i>	?
Green Sturgeon ^o	<i>Acipenser medirostris</i>	Vulnerable April 1987
Lake Sturgeon ^o	<i>Acipenser fulvescens</i>	?
Atlantic Cod	<i>Gadus morhua</i>	?
Blueback Herring ^o	<i>Alosa aestivalis</i>	RANS DR April 1980
Arctic Char	<i>Salvelinus alpinus</i>	?
Bull Trout	<i>Salvelinus confluentus</i>	Vulnerable
Mira Whitefish*	<i>Coregonus</i> sp.	Vulnerable
Opeongo Whitefish*	<i>Coregonus</i> sp.	Threatened
Lake Herring	<i>Coregonus artedii</i>	Endangered
Lake Whitefish	<i>Coregonus clupeaformis</i>	Threatened - Lakes Erie, Ontario
Acadian Whitefish ^{o*}	<i>Coregonus huntsmani</i>	Endangered April 1983
Pygmy Whitefish	<i>Prosopium coulteri</i>	?
Round Whitefish	<i>Prosopium cylindraceum</i>	Vulnerable
Pygmy Smelt	<i>Osmerus spectrum</i>	Vulnerable
Pygmy Longfin Smelt*	<i>Spirinichus thaleichthys</i>	Vulnerable - British Columbia
Redfin Pickerel	<i>Esox americanus americanus</i>	Vulnerable - Quebec
Grass Pickerel	<i>Esox americanus vermiculatus</i>	Vulnerable
Central Stoneroller ^o	<i>Campostoma anomalum</i>	Vulnerable April 1985
Liard Hotspring Lake Chub*	<i>Couesius plumbeus</i> ssp.	Vulnerable - British Columbia
Silver Chub ^o	<i>Macrhybopsis storeriana</i>	Vulnerable April 1985
Pearl Dace	<i>Margariscus margarita</i>	Vulnerable - British Columbia
Pugnose Shiner ^o	<i>Notropis anogenus</i>	Vulnerable April 1985
Bridle Shiner	<i>Notropis bifrenatus</i>	Vulnerable
Bigmouth Shiner ^o	<i>Notropis dorsalis</i>	Vulnerable April 1985
Weed Shiner	<i>Notropis texanus</i>	Vulnerable
Pugnose Minnow ^o	<i>Opsopoeodus emiliae</i>	Vulnerable April 1985
Bluntnose Minnow	<i>Pimphales notatus</i>	Vulnerable
Speckled Dace ^o	<i>Rhinichthys osculus</i>	Vulnerable April 1980
Jasper Longnose Sucker*	<i>Castostomus castostomus lacustris</i>	Vulnerable
River Redhorse ^o	<i>Moxostoma carinatum</i>	Vulnerable April 1987
Copper Redhorse ^o	<i>Moxostoma hubbsi</i>	Threatened April 1988
Striped Bass	<i>Morone saxatilis</i>	Endangered - Quebec
Pacific Sardine ^o	<i>Sardinops sagax</i>	Vulnerable April 1987
Blackstripe Topminnow ^o	<i>Fundulus notatus</i>	Vulnerable April 1985
Brindled Madtom ^o	<i>Noturus miurus</i>	Vulnerable April 1985
Northern Madtom ^o	<i>Noturus stigmosus</i>	Vulnerable April 1993
Mottled Sculpin	<i>Cottus bairdi</i>	Vulnerable - BC, Alberta
Shorthead Sculpin ^o	<i>Cottus confusus</i>	Vulnerable
Giant Stickleback*	<i>Gasterosteus</i> sp.	Vulnerable April 1980
Unarmoured Stickleback ^{o*}	<i>Gasterosteus</i> sp.	Vulnerable April 1983
Texada Stickleback*	<i>Gasterosteus</i> sp.	Vulnerable
Bluefin Tuna	<i>Thunnus thynnus</i>	?
Squanga Whitefish ^o	<i>Coregonus</i> sp.	Vulnerable April 1987
MARINE MOLLUSCS		
Northern Abalone ^o	<i>Haliotis kamtschatkana</i>	?
MARINE MAMMALS		
Minke Whale	<i>Balaenoptera acutorostrata</i>	?
Sei Whale	<i>Balaenoptera borealis</i>	?
Bowhead Whale ^o	<i>Balaena mysticetus</i>	Endangered
Blue Whale ^o	<i>Balaenoptera musculus</i>	Vulnerable
Beluga ^o Ungava Bay	<i>Delphinapterus leucas</i>	Endangered April 1988

(Continued)

TABLE 1. *Concluded.*

Species	Scientific Name	Proposed Status
MARINE MAMMALS (cont'd)		
White-beaked Dolphin	<i>Lagenorhynchus albirostris</i>	?
Killer Whale	<i>Orcinus orca</i>	?
Grey Seal	<i>Halichoerus grypus</i>	?
Harbour Seal	<i>Phoca vitulina</i>	NAR
Lake Ontario		Extirpated

*Endemic to Canada

°Updated Status Report

TABLE 2. New (since Campbell 1997: Table 3) fish and marine mammal species of possible interest to COSEWIC. (Not listed by Priority.)

Species	Scientific Name	Possible Status
SPECIES UPDATES		
Fish		
Aurora Trout	<i>Salvelinus fontinalis timagaminensis</i>	Endangered April 1987
Shortnose Cisco	<i>Coregonus reighardi</i>	Threatened April 1987
Shortjaw Cisco	<i>Coregonus zenithicus</i>	Threatened April 1987
Lake Simcoe Whitefish	<i>Coregonus clupeaformis</i>	Threatened April 1987
Redside Dace	<i>Clinsotomus elongatus</i>	Vulnerable April 1987
Silver Shiner	<i>Notropis photogenis</i>	Vulnerable April 1987
Great Lakes Deepwater Sculpin	<i>Myoxocephalus thompsoni</i>	Threatened April 1987
Marine Mammals		
Fin Whale	<i>Balaenoptera physalus</i>	Vulnerable April 1987
Harbour Porpoise	<i>Phocoena phocoena</i>	
Northwest Pacific		Indeterminate April 1991
Northwest Atlantic		Threatened April 1990
SPECIES YET TO BE CONSIDERED		
Fish		
Morrison Creek Lamprey	<i>Lampetra richardsoni marifuga</i>	?
Nass River Lamprey Species 1	<i>Lampetra</i> sp.	?
Nass River Lamprey Species 2	<i>Lampetra</i> sp.	?
Copper River Lamprey	<i>Lampetra</i> sp.	?
Pygmy Smelt	<i>Osmerus</i> sp.	
Lochaber Lake, Nova Scotia		Vulnerable
Lake Heney, Quebec		Vulnerable
Greater Redhorse	<i>Moxostoma valenciennesi</i>	Vulnerable

are published under the name(s) of the original author(s). The reports have undergone minor editing to provide a brief introduction and some degree of consistency in format and presentation.

As to the legislative proposal for a Canadian Endangered Species Act discussed in Campbell (1997), the Bill was not passed prior to the dissolution of Parliament for the June 1997 Federal Election Act and became non-existent. It remains to be seen if it, or a similar bill, will be brought forward by the current Government.

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Canadian Wildlife Service, the Canadian Museum of Nature and the Royal Ontario Museum for assistance provided in cash and kind. A special mention to *The Canadian Field-Naturalist* for assistance in publication and to Francis Cook and Claude Renaud (Canadian Museum of Nature, french abstracts) for editing as well as to all members of COSEWIC for their dedication and interest in the future of Canada's flora and fauna. We gratefully acknowledge the financial support provided by Environment Canada which permitted the contracting of several new reports.

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Updated Status of the St Lawrence River Population of the Beluga, *Delphinapterus leucas**

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Lesage, Véronique, and Michael C. S. Kingsley. 1998. Updated status of the St Lawrence River population of the Beluga, *Delphinapterus leucas*. Canadian Field-Naturalist 112(1): 98–114.

The Beluga, *Delphinapterus leucas*, in the St Lawrence Estuary is at the southern limit of the distribution of this species. The large distances separating this population from northern Belugas, its low genetic variability, and the rarity of Beluga sightings outside their normal range in the Gulf, suggest that it is isolated from its northern conspecifics. Over-exploitation and attempted extermination reduced this population to the low hundreds; it is now conservatively indexed at between 600 and 700 and is slowly increasing. Reproductive rates, survival rates at each age, and population age structure are similar to those of other Beluga populations. Factors potentially limiting the size of this population include limits on food stocks and extent of critical habitat; its growth rate may be affected by low genetic variability, boat traffic, and environmental contamination. St Lawrence Belugas are protected from hunting and are excluded from marine mammal species targeted by the whale-watching industry. Regulations and guidelines on the behaviour of marine traffic under the Fisheries Act and within the operating mandate of the Saguenay Marine Park offer some protection from disturbance although more may be needed. Pollution reductions upstream and improved controls on toxic compounds, are helping to reduce ambient levels of contaminants, but efforts to accelerate and maintain this progress are important.

Le Béluga, *Delphinapterus leucas*, dans le Saint-Laurent est à la limite méridionale de la distribution de l'espèce. La grande distance le séparant des Bélugas du nord, une faible variabilité génétique entre les individus, et les rares observations de Bélugas à l'extérieur des limites normales de leur distribution dans le golfe laissent supposer que ces Bélugas sont isolés de leurs congénères du nord. La surexploitation et des tentatives d'extermination auraient causé le déclin de cette population. Un indice prudent de son abondance actuelle se situe entre 600 et 700 individus, et elle s'accroît lentement. Le taux de naissance, le taux de survie à chaque âge, et la structure d'âge de la population des Bélugas du Saint-Laurent sont semblables à ceux des autres populations de Bélugas. Les facteurs qui risquent de limiter la taille éventuelle de cette population incluent l'abondance de nourriture et l'étendue de l'habitat critique. La faible variabilité génétique à l'intérieur de la population, la circulation maritime et la contamination de l'environnement pourraient limiter son taux d'accroissement. Les Bélugas du Saint-Laurent sont protégés contre toutes formes de chasse et sont exclus des espèces visées par l'industrie de l'observation des baleines. Des règlements et des directives visant le comportement de la circulation maritime, et émis dans le cadre de la Loi sur les Pêcheries et à l'intérieur du mandat d'opération du Parc Marin du Saguenay, offrent un certain niveau de protection contre le harcèlement. Une protection accrue pourrait toutefois être nécessaire. La réduction des émissions de polluants en amont et un niveau accru de contrôle des rejets de composés toxiques contribuent à la réduction des niveaux ambiants de contaminants. Il demeure néanmoins important d'accélérer et de maintenir ce progrès.

Key Words: Beluga, *Delphinapterus leucas*, White Whale, Béluga, threatened, St Lawrence River.

The Beluga (*Delphinapterus leucas* Pallas, 1776) is a member of the family Monodontidae. It is characterized by unfused cervical vertebrae, the absence of a dorsal fin, a rounded prominent "forehead", a thick dermis, and white colour (Figure 1). It has one close relative, the Narwhal, *Monodon monoceros* (Lint et al. 1990). In both species, the absence of a dorsal fin and the thick dermis are believed to be adaptations to living in ice-infested waters.

Newborn Belugas are slate-grey or brown. They average 1.5 m long and weigh around 78 kg. As they mature, they become bluish-grey in colour, and then progressively lighter. The pure white colour, characteristic of adults, is generally attained

between the ages of 6 and 11 years (Brodie 1971; Sergeant 1973; Burns and Seaman 1985), but on average at different ages in the two sexes (Sergeant 1959; Ognietov 1981; Burns and Seaman 1985). Most females mature sexually while still light grey, but most males become white before maturity (Burns and Seaman 1985; Doidge 1990a). Adult males are longer and heavier than females (Sergeant and Brodie 1969; Brodie 1989), the difference varying slightly between populations (Doidge 1990b). Compared with other Belugas of eastern North America, St Lawrence Belugas are of medium size (Sergeant and Brodie 1969). White females and males from hunted samples in the St Lawrence (some perhaps still growing) averaged 3.5 m and 3.6 m long respectively (Vladykov 1944); asymptotes of growth curves fitted to age-length data from beach-cast St Lawrence carcasses were 3.62 and 4.17 m (Kingsley 1996).

*At a meeting of COSEWIC on 16 April a change to "threatened" was supported by 12 votes out of 21; this majority was less than the two-thirds needed to change the status, so "Endangered" was retained.

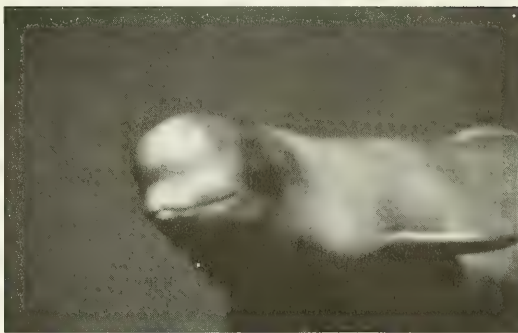


FIGURE 1. The Beluga (*Delphinapterus leucas*) photographed by Véronique Lesage in 1991. The left shows the species as usually seen in the field, taken in the St. Lawrence Estuary. The right showing details of morphology was taken at the Shedd Oceanarium in Chicago, Illinois.

Distribution and Migration

The Beluga is limited to seasonally ice-infested Arctic and sub-Arctic seas. The St Lawrence Belugas are at the southern limit of the worldwide distribution of the species (Reeves 1990). Beluga skeletons in Pleistocene clays and sand deposits in Québec (Canada) and Vermont (United States) suggest that the Beluga established itself in the St Lawrence region during the last Ice Age, about 10 000 years ago (Harington 1977). At that time, the Champlain Sea covered an area of 53 100 km² or more between Québec City and Lake Ontario, including part of the lower Ottawa River valley and the Lake Champlain valley in New York and Vermont. Belugas probably remained in the northern (lower) sector of the Champlain Sea during the retreat of the Laurentian Ice Sheet and established themselves in what would become the present St Lawrence River.

The current distribution of the St Lawrence Beluga (Figure 2) is not as extensive as that described 50 years ago by Vladykov (1944). Their distribution in the upper Estuary then extended 48 km upstream of Québec City, but now is limited to the Battures aux Loups Marins, approximately 100 km downstream of Québec City. The eastern extent of the Beluga's range in the Gulf of St Lawrence has been reduced from Natashquan to Sept-Îles along the north shore, and from Baie des Chaleurs to Cloridorme along the south shore; there are, however, occasional sightings of small numbers off the "north shore" of New Brunswick, and recent observations of small numbers in the northern Gulf in summer (Kingsley, unpublished data). The extent of their distribution in the Saguenay River has been reduced slightly from Chicoutimi to Saint-Fulgence, 12 km downstream of Chicoutimi (Michaud et al. 1990; Figure 2).

Belugas are reported outside the limits of their usual distribution each year (Pippard 1985; Sergeant 1986; Michaud et al. 1990). In eastern Canada sight-

ings have recently been reported from: Blanc-Sablon on the north shore of the Gulf of St Lawrence; Newport in the Baie des Chaleurs; the Miramichi estuary; Tracadie and Escuminac on the "north shore" of New Brunswick; Prince Edward Island; the "east shore" of Nova Scotia; Digby, Nova Scotia; the Newfoundland south coast; and along the eastern seaboard as far south as New Jersey (38°55'N) in the United States (Reeves and Katona 1980; Michaud et al. 1990; Kingsley unpublished data). Belugas are also seen, from time to time, on the Labrador and the east coast of Newfoundland. The origin of most of these animals is uncertain. Belugas within the Gulf of St Lawrence are almost certainly from the St Lawrence population; two east-coast strandings in Newfoundland had low levels of organochlorines, so were probably Arctic animals (Muir et al. 1996a); the mtDNA from a Beluga living in Guysborough Harbour, on the "east shore" of Nova Scotia, suggested that it was from the St Lawrence, and not the Arctic (J. Clayton, Department of Fisheries and Oceans (DFO), Freshwater Institute, Winnipeg, Manitoba, personal communication). Whales on the Gaspé shore of the Estuary are susceptible to being swept eastward and southward by the Gaspé current (Sergeant and Hoek 1988). Sightings in the western and northern Gulf seem more frequent in the spring and early summer (Sergeant and Brodie 1975; Sergeant 1986).

Migration

St Lawrence Belugas move seasonally, but compared with their Arctic conspecifics they are relatively sedentary (Figure 2). The summer distribution is centred at the mouth of the Saguenay River and extends in the Saguenay to Saint-Fulgence and in the St Lawrence Estuary from the Battures aux Loups Marins to Les Escoumins on the north shore, and to Saint-Simon-sur-Mer on the south shore (Michaud et al. 1990; Michaud 1993a; Kingsley 1993, 1996). An extension of the summer distribution to Rivière

Portneuf (30 km downstream of Les Escoumins) has recently been noted (Michaud 1993a; Kingsley 1996). In fall, Belugas are distributed mostly as in summer, but there is a more intensive use of the Estuary downstream of the Saguenay River, and the upper limit of their distribution in the Saguenay River is reduced to Baie Ste-Marguerite (Boivin and INESL 1990). A general movement downstream begins in late September or early October. The winter distribution is not completely described, but probably includes all the estuary downstream of the Saguenay and extends as far east as Cloridorme on the south shore and Sept-Iles in the north-western Gulf (Michaud et al. 1990; Kingsley, unpublished data). Winter distribution may be related to the migration of prey (Boivin and INESL 1990), and reflects the availability of loose ice or open water (Vladykov 1944). In spring, Belugas are widely distributed, moving into the upper part of the Estuary, between the Saguenay River mouth and the Battures aux Loups Marins, while late migrants may also be seen near Cloridorme and Pointe des Monts (Michaud 1990), or around south-west and western Anticosti Island (Kingsley, unpublished data). The spring movements may follow the migrations of Capelin (*Mallotus villosus*) and Herring (*Clupea harengus*) from east to west along the north shore (Bailey et al. 1977).

Stock Discreteness

The nearest neighbours to the St Lawrence River Belugas winter in Hudson Strait, off south-east Baffin Island and off western Greenland (Reeves 1990). Regular Beluga sightings along the Newfoundland and Labrador coasts before the early 1900s (Reeves and Katona 1980; Pippard 1985; Sergeant 1986; Reeves 1990), as well as an increase in Beluga numbers in the St Lawrence during the late 1920s that was attributed to immigration (Vladykov 1944: 141-142), suggest that occasional immigrations may have slowed the decline of the St Lawrence population (Mitchell and Reeves 1981; Pippard 1985; Reeves and Mitchell 1987). Belugas are still seen along the Labrador coast (Curren and Lien 1995), but significant immigration is no longer likely to occur because Beluga populations that summer in eastern Hudson Bay, Ungava Bay and Cumberland Sound are depleted (Reeves and Mitchell 1989; Richard 1991, 1993).

A lower level of nuclear genetic variation within the St Lawrence Belugas than that of the Beaufort Sea population (which totals about 11 500 whales) was interpreted as suggesting that the St Lawrence population lacks significant genetic exchanges with other populations and is composed of related individuals; it therefore may suffer from inbreeding depression (Patenaude et al. 1994). The mtDNA analyses shows that St Lawrence Belugas are more closely related to Hudson Strait and east Hudson

Bay populations (Brown and Clayton 1993), so comparing their genetic variability with that of those neighbouring populations, or with their own pre-exploitation level (Patenaude et al. 1994), would be more informative.

Protection

International Protection Measures

The parties to the *International Convention to Regulate Whaling* have not decided that the convention applies to small whales like the Beluga. Canada is not a signatory. However, bipartite agreements for management or research, or both, that are of significance in the protection of Canadian Beluga stocks exist between Canada and Greenland, and between the Inuvialuit of the western Canadian Arctic and the people of Alaska.

The listing of the Beluga on Appendix II of the Convention on International Trade in Endangered Species of Flora and Fauna (CITES) restricts international trade only to the extent of requiring export permits. Presently, there is no known international trade in Beluga products, apart from the supply of live animals to zoos and oceanaria. Live Belugas have not been exported from the St Lawrence for a long time, and the Canadian Department of Fisheries and Oceans has suspended all permission for live exports from Canada since December 1992. The only region affected by this decision is Churchill which was, since 1970, the principal source of captive Belugas for Europe, Japan and North America.

National Protection Measures

Beluga Protection Regulations under the *Fisheries Act* date from 1949 and have since then been frequently altered and extended (Reeves and Mitchell 1989); in 1979 the St Lawrence, Labrador and Newfoundland were added to the geographical scope and the St Lawrence was closed to hunting. In February 1993, the Beluga Protection Regulations were superseded by, and absorbed into, the *Marine Mammal Regulations* of the Fisheries Act. These regulations generally forbid disturbance of marine mammals. These clauses were intended to control whale-watching, a popular recreational activity and a flourishing industry in the St Lawrence Estuary. No permit, other than those relating to marine safety, is required to conduct whale-watching cruises in Canada. However, an informal agreement exists between the Canadian Department of Fisheries and Oceans and commercial whale-watching cruises in the St Lawrence Estuary to exclude Belugas from the species sought by whale-watching boats. The Department has also established behavioural guidelines for vessels that unexpectedly encounter Belugas (Ministère des Pêches et des Océans 1992). The harassment sections of the Marine Mammal Regulations could be regarded as a safeguard if the code of ethics were not respected, but are difficult to

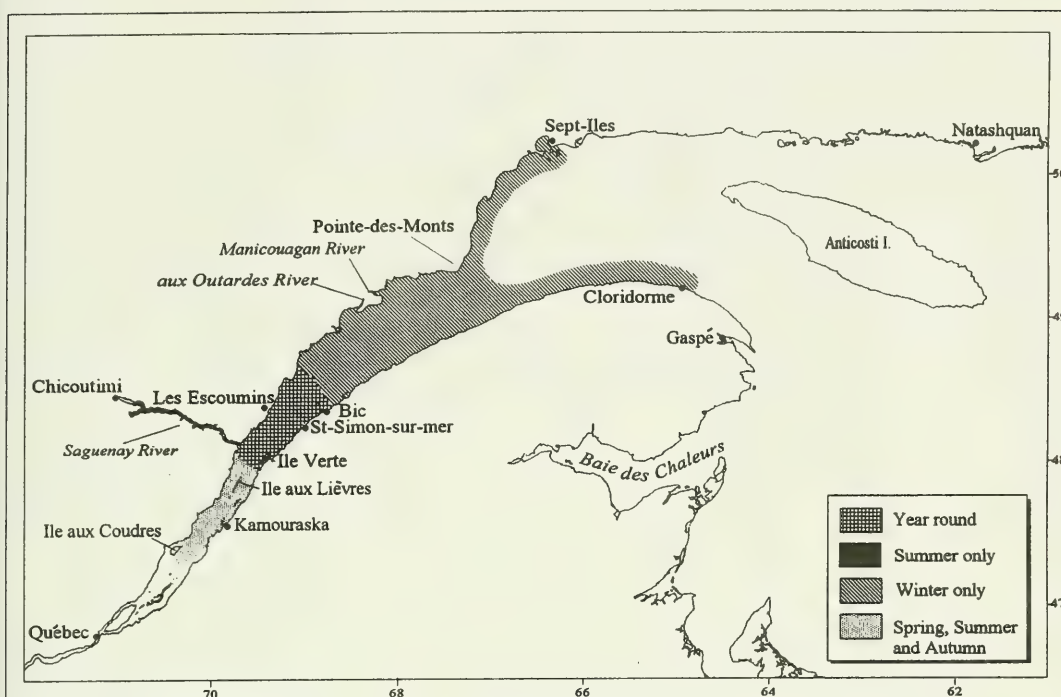


FIGURE 2. Seasonal distribution of the Belugas of the St Lawrence.

enforce. The creation of the Saguenay-St Lawrence Marine Park may provide a further level of control over a part of the summer habitat of the population, but also increases publicity for the area.

At the provincial level, the Québec *Threatened and Vulnerable Species Act* allows the Minister to designate species threatened or vulnerable and to act to protect them or their habitats.

Population Size and Trends

A Beluga fishery flourished along the St Lawrence River between the late 1500s and the early 1950s, and was intense between 1860 and 1945. From records of traded oil and skins, Reeves and Mitchell (1984) estimated that about 15 000 Belugas were removed from the St Lawrence population between about 1880 and 1950; this may have been an overestimate as commercial records often did not distinguish between products obtained from Belugas and those from other species (Reeves and Mitchell 1984). Such a harvest could have depleted a population numbering even several thousand in the 1880s to a few hundreds by the middle of the twentieth century (Reeves and Mitchell 1984). Hunting probably continued throughout the 1970s, and it has been suggested that approximately 25 whales per year were then still being removed (Pippard and Malcolm 1978).

Studies from 1973 to 1996 have produced popula-

tion or index estimates ranging from 300 to 705 (Table 1; Figure 3). Most have been aerial surveys, either visual (uncorrected for diving animals) or photographic (with a minimum diving correction) but boat surveys have also been tried. Sample surveys of the distribution area (Sergeant and Hoek 1988; Kingsley and Hammill 1991; Kingsley 1993, 1996), as well as complete-coverage surveys of the most highly frequented areas (Pippard and Malcolm 1978; Béland et al. 1987b) have been carried out. While all are *bona fide* attempts to estimate a population index, the variations in method impose caution in comparing their results. Since 1984, vertical large-format photography has been used, combined since 1988 with standard sample designs using transects across the river (Sergeant and Hoek 1988; Kingsley and Hammill 1991; Kingsley 1996). Surveys conducted in 1988, 1990, 1992, and 1995 gave index estimates of between 490 and 705 Belugas using a correction factor of 15% to account for diving animals (Kingsley 1996). A standardized conservative index, smoothed on a linear trend with previous estimates, is 650 for 1995, with estimated standard error 45. The diving behaviour of monodontids in Arctic Canada suggests survey correction factors near 80% (Martin and Smith 1992; Martin et al. 1994), which if applied to the St Lawrence surveys would greatly increase the population estimate (Innes 1996). This has not been done, as conditions in the St Lawrence

TABLE 1. Population index estimates for Belugas of the St Lawrence estuary, 1973 to 1995.

Year	Boat Aeroplane, Helicopter	Photo- graphic, Visual	Sample survey (%) or Total Count	Coverage		Count	Index estimate	Limits (–) or standard error (±)	Source
				Peripheral Range	Saguénay				
1973	A	P	S-08	N	N	43	443	229–658	Sergeant and Hoek 1988
1977	H	V	T	N	Y	266		300–350	Pippard 1985
1982	H	V	S-28	Y	Y	143	512	360–715	Sergeant and Hoek 1988
1984	A	P	S-39	N	Y		431	187–773	Sergeant and Hoek 1988
1984	B	V	S	N	N		495	±245	Lynas 1984
1985	B	V	T	N	Y	161–165		<340	Béland et al. 1987
1985	A	P	S-85	N	N	379	530	285–775	Sergeant and Hoek 1988
1985	A	P	S-85	N	N	295–369		275–450	Béland and Martineau 1985
1988	A	P	S	Y	N	152	491	±69	Kingsley and Hammill 1991
1990	A	P	S	Y	N	148	606	±308	Kingsley and Hammill 1991
1992	A	V	S	Y	Y	490		>490	Michaud 1993a
1992	A	P	S-50	Y	Y	230	525	410–725	Kingsley 1993
1995	A	P	S-50	Y	Y	336	705	540–1035	Kingsley 1996

Notes:

Pippard's highest two counts in eight surveys of the core range were 262 and 266. She added 35–85 to allow for unseen Belugas, especially in the peripheral range which was surveyed separately.

Sergeant's photographic surveys in 1984–1985 were corrected for diving animals by adding 18% to photo counts; surveys in 1988–1995, by only 15%. These corrections were separate from factors applied to estimate total index from the sample survey count. Photo counts in 1988 and 1990 also had a glare correction (mean value 2.2%) added, not added in 1992 and 1995.

Sergeant's 1985 survey may have flown over, and photographed, some Beluga groups twice (Béland and Martineau 1985; Sergeant and Hoek 1988); Béland and Martineau (1985) corrected for this by matching up photo frames and identifying and removing double counts. Their upper limit includes a 25% correction for all unseen animals, i.e., those diving and those in unphotographed areas.

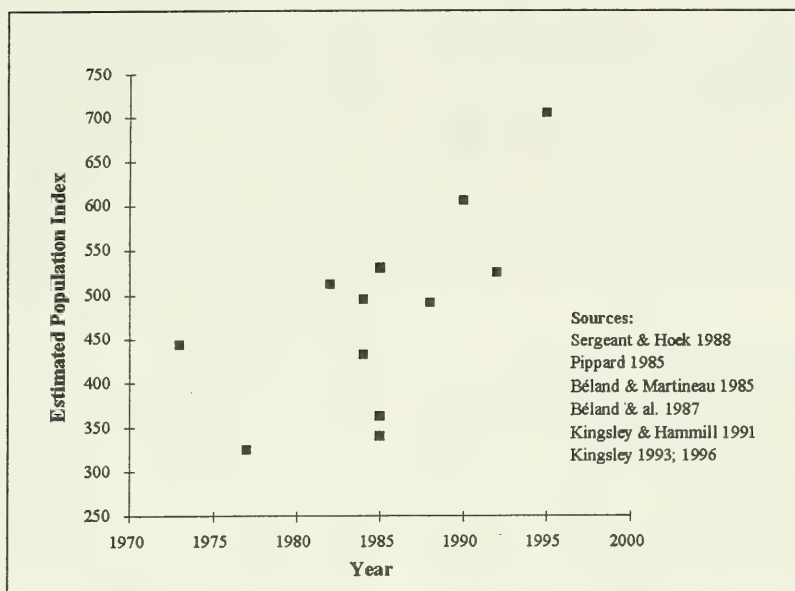


FIGURE 3. Population index estimates for the St Lawrence Belugas, 1973-1995.

are different, and no similar work has been done here.

Béland and Martineau (1985) deduced (from three data points) that the population declined at 6%/year from 1963 to 1985, but the current population size is very different from their prediction, and survey results in the 1980s and 1990s have consistently failed to support the thesis of a declining population. In the absence of resource limitations, a zero growth rate is intrinsically unlikely, and all current evidence, from birth-rates, age at death, and survey data, suggest an increasing trend (Kingsley 1996). A longer series of surveys will help to establish an unarguable past trend for the index; current trend may, however, remain uncertain.

In an attempt to generate more immediate information on growth rates, Béland et al. (1988) developed an age structured population model. Age-specific birth rates were obtained from Alaskan data (Burns and Seaman 1985), and mortality rates from the ages of beach-cast St Lawrence Belugas; animals were assumed to turn white at maturity. They concluded that the limit between an increasing and a decreasing population occurred when the population contained 28 to 30% grey animals (excluding young of the year). Recent observations of the fraction of grey animals in the population vary from 29 to 32% (Michaud 1993b; Desrosiers 1994), and suggest that the St Lawrence Beluga population is not growing fast. However, the effects of the various assumptions in these models were not fully explored and the proportion of grey animals, while a useful index, does

not provide a calibrated measure of population growth rate (Kingsley and Hammill 1993). Data from different populations cannot be used to calibrate it, as site-specific ecological and hunting pressure can alter fecundity and survivorship schedules (Doidge 1990a). Counts and measurements of short animals on aerial survey film, while imprecise, have suggested that the birth rate may be quite variable from year to year, but is probably not, overall, seriously reduced (Kingsley 1996).

Habitat

Typical Habitat

Belugas inhabit cold waters. The winter distribution of the Beluga generally coincides with 4-8/10 ice cover in areas over the Continental Shelf (Jonkel 1969; Fraker 1979; Finley and Renaud 1980). In summer, they concentrate in the warm, shallow, turbid waters of Arctic river-mouths, but the reasons for this are not understood; suggestions include calving (Sergeant 1973; Finley 1982), breeding (Brodie 1971), feeding (Kleinenberg et al. 1964; Tomilin 1967), or moult (Finley 1982; Finley et al. 1982; St. Aubin and Geraci 1989; Reeves and Mitchell 1989; St. Aubin et al. 1990).

The presence of this Arctic species in the St Lawrence Estuary is favoured by cold, productive waters and seasonal ice cover. A cold, west-bound deep current in mineral-rich Laurentian Channel along the north shore comes against a sill at the confluence of the Saguenay River and the St Lawrence Estuary, creating an upwelling of mineral-rich

waters. This area has strong tidal and set currents and precipitous bottom topography that create frequent ocean fronts and discontinuities, capable of concentrating prey. The lower St Lawrence Estuary is fed by several large freshwater sources: the Saguenay, Betsiamites, aux Outardes, and Manicouagan rivers, some of which could provide additional shallow estuarine summering areas. Upstream of the Saguenay, Belugas find shallower, warmer, and more turbid water, and a pattern of islands that may serve as protection from wind and rough seas.

Areas Intensively or Regularly Frequented

Group pattern and herd composition has been most studied from July through September, but may vary with season (Michaud and Chadenet 1990). About 45% of the animals are typically observed downstream of the Saguenay mouth; they are most often clustered near the head of the Laurentian Channel and along its southern scarp, but the distribution sometimes extends to Pointe au Boisvert on the north shore and St-Simon-sur-Mer on the south shore. Groups of adults may be seen throughout this area, but adults with young tend to be in the upstream part, toward the Saguenay mouth and the south shore (Michaud 1993a; Kingsley 1993, 1996). However, an unusual number of grey juveniles were seen along the north shore between Begeronnes and Les Escoumins throughout the summer of 1994. Another 50% of the population is usually distributed upstream of the Saguenay, where herds usually number less than 30 and include over 30% juveniles (Sergeant 1986; Sergeant and Hoek 1988; Kingsley 1996). Thirteen "highly frequented areas" have been defined upstream of the Saguenay mouth as far as the Île aux Coudres (Michaud 1993a). The remaining 5% of the population may, on average, be found in the Saguenay fjord, usually near its mouth or at Baie Ste-Marguerite. Biological and physico-chemical characteristics of most of the sectors are summarized by Michaud et al. (1990), and behaviours associated with differing habitats are presented in Pippard (1985).

Temporal Variations in Preferred Sectors

There is emerging evidence for short-term seasonal variation in preferred sectors, even within the summering area. It appears from a study conducted during the presumed spawning period of the Herring in the Île-aux-Lièvres region that St Lawrence Belugas may take advantage of resources abundant in specific sectors during short periods of time (Lesage and Kingsley 1995). Belugas may exploit other sectors such as the sandbanks between Isle-Verte and Trois-Pistoles where Herring gather before spawning (Bio-Conseil Inc. 1982) or the Batture aux Alouettes where Capelin spawn between mid-April and mid-May (Parent and Brunel 1976); they are

seen in the port of Rivière-du-Loup, but usually only in spring. However, the seasonal movements from spring to fall have not been described in detail.

The intensity with which some sectors are used varies on the longer time scale. Michaud et al. (1990) and Kingsley (1993) recently noted in 1990 to 1992 an increased number of Beluga in the southern portion of the Estuary downstream of Île Verte whereas other sectors, such as the Saguenay River, Tadoussac Bay at the mouth of the Saguenay River, and the Manicouagan banks, which were formerly regularly frequented by Belugas, were less visited. Reasons for the reduced frequentation or desertion of such sectors are difficult to establish and may involve different factors. Disturbance by human activity has been suggested as the reason for the paucity of sightings in Tadoussac Bay, and the 60% reduction in the frequency of passage of Beluga at the mouth of the Saguenay River (Caron and Sergeant 1988). Over-exploitation, or modifications of biological or physico-chemical characteristics of the habitat (temperature, salinity or flow patterns) resulting from hydroelectric development have been suggested as possible reasons for the distributional changes observed in the Manicouagan banks region (Laurin 1982b; Pippard 1985). In gregarious species such as the Beluga, a reduction in the population size may result in the desertion of peripheral range (Brown 1984; Gaston and Lawton 1990). This could also account for other restrictions in distribution, such as reduced occurrence in the Baie des Chaleurs, the lower North Shore, and regions upstream of Île aux Coudres.

Changes in Quality of Habitat

Within the St Lawrence drainage basin, industrialisation, agriculture, and urbanisation have resulted in discharges, both accidental and deliberate, of several pollutants into the St Lawrence and Saguenay rivers and their tributaries. They include mercury, lead, polycyclic aromatic hydrocarbons (PAHs), and a wide range of organochlorines of varying persistence and toxicity; the St Lawrence Beluga Recovery Plan (Bailey and Zinger 1995) reviews the spectrum in detail. Water power is available in large quantities from the rivers running into the Saguenay fjord and the north side of the St Lawrence Estuary, and has attracted industries that have released contaminants. Among them are, or were, chlor-alkali plants (mercury) and aluminium smelters (PAHs). Mirex, a stable organochlorine used as a stabiliser and a pesticide, was produced on the south side of Lake Ontario; PCBs, used as flame retardants, are ubiquitous; so are many pesticides, including DDT. The St Lawrence drains the intensively-farmed land of southwestern Québec, southern Ontario, and parts of the northern United States, and picks up agricultural pesticides. Many of these compounds are toxic; some much more than others.

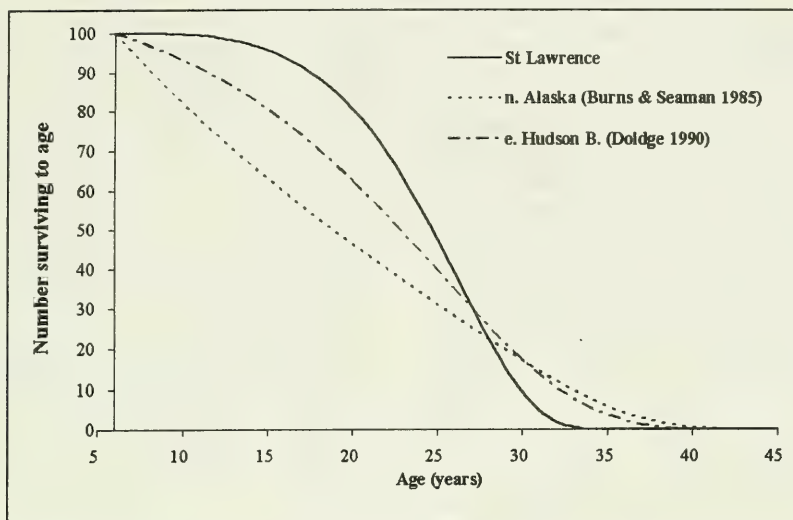


FIGURE 4. Competing-risk curves of adult survival (Siler 1979) fitted to data from beach-cast St Lawrence Beluga carcasses and to hunted samples from Arctic populations.

However, over the last 20 years, habitat quality has improved; to the extent that 70% of the 56 recommendations made in the St Lawrence Beluga Recovery Plan were found to have been anticipated by the government departments responsible (Bailey and Zinger 1995; SLV-2000 1996). The most dangerous OCs, notably PCBs and DDT, are better controlled. Under the St Lawrence Action Plan initiated in 1988, toxic discharges have been reduced and further reductions are targeted as federal and provincial regulations for pulp and paper mills are implemented (SLV-2000 1996). Of 246 admissible Québec riparian municipalities, 126 are now connected to waste water purification plants (Environnement Canada 1993). Contaminant levels have dropped in birds and mammals (Muir et al. 1996b), and at lower trophic levels. Between 1982 and 1992, PCB levels in American Eels (*Anguilla rostrata*), have declined by 68% and Mirex by 56% (Hodson et al. 1994); mercury concentrations in shrimps and Blue Mussels (*Mytilus edulis*) have also declined (Cossa and Desjardins 1984; Cossa and Rondeau 1985; Pelletier et al. 1989); so have organochlorine levels in other faunal elements of the Great Lakes and Gulf of St Lawrence (Environment Canada 1991; Beck et al. 1994).

But marine traffic may also affect the quality of Beluga habitats. The St Lawrence River is an international waterway with a high volume of commercial and recreational ship traffic. In recent years, whale-watching has become an important economic activity. While it is centred in Tadoussac and Baie Ste-Catherine, companies involved in this activity are being established in several communities along the north and the south shores of the Estuary. Although the industry mostly targets Fin

(*Balaenoptera physalus*) and Blue (*Balaenoptera musculus*) whales, not Belugas (which are forbidden to it), much of its activity is off Tadoussac Bergeronnes Les Escoumins, where almost half the Beluga population can sometimes be found (Michaud 1993a; Kingsley 1996).

Habitat Protection

The *Fisheries Act*, the *Canada Shipping Act* and the *Canadian Environmental Protection Act* are the principal legislative instruments available to govern the release of toxic substances into aquatic habitats. There is no legislative act which specifically controls marine traffic for the benefit of marine mammals, but the *Marine Mammal Regulations* of the Fisheries Act prohibit deliberate harassment. The *Canada Wildlife Act* authorizes the Minister of the Environment to create National Wildlife Areas, and the *Canada Oceans Act* is expected to permit the creation of Marine Protected Areas; either could be applied to protect cetacean habitats. Guidelines established by the Canadian Department of Fisheries and Oceans have identified critical sectors within the St Lawrence Beluga summer range for boaters to avoid, and in the context of the Management Plan for the Saguenay-St Lawrence Marine Park, additional areas may be considered for protection.

At the provincial level, the Québec *Environmental Quality Act* gives the Minister certain powers to protect the environment in general, and the *Wildlife Conservation and Development Act* establishes zones for the protection of wildlife habitat. The *Watercourses Act* gives the provincial Minister responsible some powers over banks and beds of fresh and marine water-bodies.

General Biology

Reproductive Capability

In Arctic Belugas, females mature sexually between age 4 and 7 years; males, between age 8 and 9. The mating period varies between populations and is thought to occur in the St Lawrence Beluga between April and June. A female usually bears a single calf (Vladykov 1944; Kleinenberg et al. 1964) after 14.5 months' gestation. Births in the St Lawrence generally occur in July and August (Vladykov 1944; Sergeant 1986; Béland et al. 1990; 1992). Lactation, which continues over 20 to 24 months, may partially overlap the following gestation (Vladykov 1944; Brodie 1971; Sergeant 1973; Doidge 1990). The incidence of gestation in sexually mature females suggests a three-year reproductive cycle.

Reproductive parameters of the St Lawrence Beluga are difficult to establish. The examination of reproductive tracts of stranded carcasses suggests that the reproductive rate of St Lawrence Belugas is low: less than 21% of the sexually mature females examined were pregnant or lactating (Béland et al. 1992). However, these animals had all died of disease or old age, and almost 60% (20 of 34) of them were beyond the age at which fertility starts to decline (Burns and Seaman 1985). Modelling of monodontid populations indicates that the gross annual birth rate should be around 9 to 10% (Burns and Seaman 1985; Kingsley 1966). Surveys of neonates of St Lawrence Belugas soon after the calving period produced reproductive rate estimates of 8.1, 9.0 and 9.9%, similar to estimates of birth rate predicted by models, but 31 to 38% lower than in the Arctic (Lynas 1984; Sergeant 1986); however, in a subsequent publication these estimates were revised downward to about 5.5%/year (Sergeant and Hoek 1988). The Arctic rates of 12 to 14% used for comparison may be too large (Kingsley 1996), and estimates of 10% for both the Bering Sea and Cumberland Sound Belugas (Brodie 1967; Burns and Seaman 1985), are much closer to those obtained for the St Lawrence population. The reproductive rate of the St Lawrence Belugas has also more recently been estimated by censusing immature animals soon after the birth period. These estimations, which vary between 12.5 and 32% of the total population size, are similar to, or slightly lower than, those obtained for Arctic populations (Lesage and Kingsley 1995). Neonates and juveniles together compose only about 20% of strandings, possibly indicating a low birth-rate, high juvenile survival, or both (Béland et al. 1988; Bailey and Zinger 1995), but also reflecting sampling bias if they are more apt to sink than the fat adults that compose most of the strandings (Béland et al. 1992).

Survival

Age-specific mortality has been estimated from the age structure of whales that have died from natu-

ral causes and have been recovered. However, mortality rates calculated from this sample could be biased, as young animals may be more apt to sink, and may be under-represented (Béland et al. 1987a, 1988). The apparent life expectancy at maturity is about 16 years (Kingsley, unpublished data; Figure 4) equivalent to an average annual adult mortality of about 6.5%; Béland et al. (1992) estimated overall annual mortality at 3 to 4%. Estimates of life expectancy are biased downward, owing to the difficulty of reading the occluded and worn teeth of very old animals (Béland et al. 1987a). Compared with two Arctic populations, there are more Belugas in the St Lawrence population at adult ages up to the late 20s (Figure 4); the Arctic populations appear to live longer as there are in both samples some Belugas in the age range 34 to 38, absent* in the St Lawrence.

Behavioural Adaptability

Behavioural responses of Belugas to vessel traffic have been examined in many parts of their range. As expected, their response varies, which may be a function of the degree of exposure, the type of approach and the frequency range of noise generated by passing traffic, and the animal's biological requirements (e.g. feeding, breeding, calving or moulting [Macfarlane 1981; Finley et al. 1982, 1990; Fraker 1983; Pippard 1985; Hazard 1988; Blane 1990; Cosens and Dueck 1993; Lesage 1993]). The animal may thus stay in an area until its threshold of tolerance is reached, leading to an apparent negative response, including desertion of the favoured area (Ford 1977; Brodie 1981; Richardson et al. 1983; Finley 1990; Caron and Smith 1990). Belugas in the St Lawrence Estuary and the Mackenzie River Delta in the Beaufort Sea, areas with the greatest exposure to traffic, appear to be the most tolerant of shipping activity, while Belugas along the ice edge in the high Arctic emit what are presumed to be alarm calls when ships are still 80 km away, and show strong avoidance reactions at 50 km (Finley 1990; Finley et al. 1990). In contrast, Belugas in the St Lawrence Estuary are often seen close to boats, and sometimes show only subtle reactions to perturbation, such as progressive movement away from the track of a vessel, slightly longer dives, and changes in their vocal behaviour (Pippard and Malcolm 1978; Blane 1990; Lesage 1993). However, some vocal changes may also impair communication.

Noise, low frequency vibrations, or human presence may cause damage to the auditory system, induce hormonal or digestive imbalances, or result in

*This observation is liable to be modified by the recovery on 25 May 1996 at Escuminac, New Brunswick of a dead female Beluga, 37+ to 39+ years old (McAlpine and Kingsley, *in preparation*).

reproductive failure (Fletcher and Busnel 1978; Geraci and St. Aubin 1980; Richardson et al. 1983; St. Aubin and Geraci 1988, 1990; Ketten et al. 1993). In addition, humans may negatively affect wildlife through interference with their activity or perception of sound.

Food Habits and Feeding

In an extensive study of the summer food habits of the St Lawrence Beluga in the late 1930s, close to 50 different invertebrate and fish species were identified, including cephalopods and polychaete worms, and fish such as the American Sand Lance (*Ammodytes americanus*), Capelin, and Greenland (*Gadus ogac*) and Atlantic (*Gadus morhua*) Cod (Vladykov 1946). Atlantic Herring, Three-spine Stickleback (*Gasterosteus aculeatus*), Rainbow Smelt (*Osmerus mordax*) and American Eel are also considered potential prey. The winter diet of St Lawrence Belugas is not known. In Alaska, the major part of the Beluga diet is composed of few species, but preferred species vary with the season and habitat, and with the sex and age of the animal (Kleinenberg et al. 1964; Lowry et al. 1985).

Limiting Factors

There is little evidence that any extrinsic factor is currently limiting either the size or growth of this population. We discuss two kinds of potential limiting factor — those that regulate the size of a population, and those that, while not controlling size directly, may limit growth rate of a population or cause its decline.

The population of Belugas in the St Lawrence has been back-calculated, from estimated catches, to have numbered a few thousand in the late 1800s (Reeves and Mitchell 1984), so there should now be a surplus carrying capacity in the habitat. Natural factors limiting the size of Beluga populations are not well known, and habitat changes that would have reduced the carrying capacity have not been identified. Finite food resources, and competition from other species including increasing numbers of seals, have obvious potential to limit populations, but there is no information on whether they are now having an effect (Bailey and Zinger 1995). Interspecific competition could become a serious menace if global warming were to reduce or eliminate winter ice cover in the St Lawrence, as Belugas do not elsewhere live in areas that are ice-free all year. Reduction in the amount of critical habitat, such as the formerly frequented mouths of the Rivière aux Outardes and the Betsiamites River, has been suggested as a limiting factor (Pippard 1985), and ascribed to change in flow regime due to dams. However, critical habitat for the species or this population has not been defined, limiting densities in Arctic estuarine summering areas are higher than any seen in the St Lawrence, and evidence for down-

stream effects of dams on estuarine habitat for Belugas is equivocal (Bailey and Zinger 1995). In the upper estuary, the population now frequents the same sectors as in 1977 (Pippard and Malcolm 1978; Michaud 1993a; Kingsley 1996) and seems not to be greatly expanding its use of new areas. To continue using these sectors, it has to tolerate increasing levels of noise and human activity. The number of whale-watching companies operating near the Saguenay has increased from 13 to 20, the number of vessels has increased from 22 to 34, and the number of departures has more than doubled (GREMM 1993). Kayak tourism near Baie Ste-Marguerite is also increasing. These activities might limit population size if the areas are critical to reproductively active females.

The growth rate of the population is limited to 4%/year or less by the low reproductive rate (0.16 ♀/♀/year) typical of the species (Innes 1996), and low genetic variability may further reduce it (Patenaude et al. 1994). If marine traffic disturbs females with young, and thereby affects juvenile survival, it might further limit population growth.

Environmental contamination may limit population growth by adversely affecting birth rate or survival (Martineau et al. 1987; Béland et al. 1992). St Lawrence Belugas have higher levels of lead, mercury, and selenium, although less cadmium than most Arctic whales (Wagemann et al. 1990; Béland et al. 1992), and PCB, DDT and Mirex concentrations in males from the St Lawrence are 25, 32 and 100-fold higher than in Arctic males (Muir et al. 1990). Marine mammals acquire contaminants chiefly in food. Marine and estuarine fish in the St Lawrence are not highly contaminated, but American Eels migrating from industrialised areas near the Great Lakes and upper St Lawrence may bring significant quantities of fat-soluble contaminants into the Estuary (Khalil et al. 1985; Lunn et al. 1987; Gagnon et al. 1990; Muir et al. 1990; Cossa 1990; Hickie et al. 1991; Béland et al. 1992; B. E. Hickie, in preparation: Development models for chemical accumulation by Arctic Marine Mammals; see also Muir et al. 1996a). However, levels of PCBs in eels (about 6 ppm in 1982) and of Mirex (0.2 ppm) had decreased by factors of 3 to 4 by 1990 (Hodson et al. 1994). Most Belugas so far examined for contaminant burdens were born during the late 1960s and early 1970s, and thus reflect a history of long exposure to high levels of contaminants.

Neonates (0+ years) and juveniles (1 to 5 years) each compose only about 10% of strandings; assuming that the population was stationary, and the stranding rates record unbiased, Béland et al. (1988) concluded from this that the birth rate was much reduced, but partly compensated by high juvenile survival. Reproductive failure has occurred in seals and mink experimentally fed diets high in

organochlorines (Reijnders 1986; Brouwer et al. 1989). However, seals are not cetaceans, and "there are few published data for cetaceans that allow testing of the hypothesis that there are comparable effects" (IWC 1995). The absence of any controlled experimental study in Beluga or other cetacean species of the effect of contaminated diets led Addison (1989) to conclude that the results presented by Martineau et al. (1987) on the St Lawrence Beluga were inconclusive in associating high organochlorine levels with reduced reproductive rates. Dead beach-cast females have lower than normal levels of recent reproductive activity (Béland et al. 1992), but this sample is biased in respect of age and health relative to Belugas alive in the river; in earlier life, ovarian scars accumulate at a normal rate (Sergeant 1986). Direct counts of juveniles in aerial photographs (Kingsley 1996), or of grey juveniles from boats (Michaud 1990), do not show that the overall proportion of young animals is much lower than normal. Stranding or recovery biases could cause a shortage of juveniles in the stranding record.

Necropsies of carcasses found on the shores of the St Lawrence have shown that Belugas usually die of disease and that other causes are rare; ailments of the alimentary canal appear to be the most frequent (Béland et al. 1992). It has been suggested that the population generally suffers from immunosuppression, due to OCs, that results in a high incidence of tumours, multi-systemic lesions, and periodontitis in St Lawrence Belugas, and contributes to the premature death of highly contaminated animals (Béland et al. 1992). This hypothesis merits further investigation; tissue sampling from live-caught animals in the St Lawrence would allow direct evaluation of some aspects of the immune system. Contaminant burdens increase with age (Béland et al. 1993), and the age distribution of stranded carcasses does not show a pattern of early deaths of highly contaminated animals (Sergeant 1986; Béland et al. 1988) as would be expected if organochlorines were having a significant immunosuppressive effect. Instead, the pattern of mortality appears to follow the typical J-shaped mammalian pattern (Caughley 1977). The distribution of ages at death is similar for males and females, although OC levels are 1.5 to 2 times higher in males. Contaminants may be implicated to some extent in some deaths of St Lawrence Belugas, but how many, which ones, or to what extent, is impossible to determine; age at death is on average high, and early death does not seem to be limiting population growth (Figure 4).

In the St Lawrence, collision with ships, or entrapment in fishing-gear are not major causes of mortality. Under a stranding program initiated in 1982, one possible ship strike was reported by Béland et al. (1992); one definite ship strike also occurred in 1995 and one in 1996. Incidental catches of Beluga in gill

nets have occurred in the past, but a mail survey conducted during 1989 and 1990 did not report any incidental catches of Beluga in recent years (Fontaine 1992). Belugas have good directional underwater hearing, and a well developed echolocation system capable of functioning in "noisy" environments (Turl 1990); but so have other odontocetes that often get tangled in fishing gear (Au 1993). The low incidence of entrapment observed in St Lawrence Belugas might, therefore, rather be the result of a small fishing industry in this region.

Special Significance of the Species

The St Lawrence Estuary is remarkable for the diversity of its cetacean fauna, to which the presence of an Arctic species at 46° North latitude makes a significant contribution. The white colour of the Beluga, its gregariousness, and its estuarine habits make it highly visible, and a popular tourist attraction. The uncertain future of this population has made it a symbol of the condition of the St Lawrence River. The impact of these factors is all the greater because the presence of Belugas in North American aquaria and oceanaria has made this playful and perpetually "smiling" whale known to many people.

Arctic populations have not been affected by environmental problems, but some that, like the St Lawrence population, were heavily hunted for marketable products, remain depleted (Reeves and Mitchell 1989; Richard 1991).

Evaluation

The recent favourable changes in certain indices of population dynamics, notably the proportion of young visible on aerial photography, and the estimated population index, suggest that the population may be recovering. Survival of adults, determined from age at natural death of stranded animals, appears high and stable, and birth rates appear normal. Levels of mortality from predation, stranding, ice entrapment, fishing gear, and hunting seem to be low. There is no evidence of downward trend in population size. Ambient environmental contaminant levels are falling, even if slowly. Finally, active programmes are in place to improve habitat quality by controlling pollution, and by acting against disturbance from shipping and pleasure boats.

However, the population is apparently separated, with little chance of replenishment from or genetic exchange with other groups of Beluga, which places it at increased risk. The maximum natural rates of increase and turnover of the species are low. The population is not large, especially for a large mammal with a low reproductive rate, and the genetic variability of the population appears reduced. Contaminant burdens are high in stranded carcasses; if this implies high levels in the living population, they may be continually under physiological stress.

Habitat quality, especially in summer, is moderate; it is downstream of a highly industrialised and intensively farmed area. It is also subject to heavy marine traffic. The whole population is concentrated in a small area of the Estuary in summer, so all its members run the same risks.

"Endangered" status is applied to populations or species that are in **imminent danger of extinction or extirpation**. The existing status of "Endangered" was based upon Pippard's (1985) evaluation that the size of the population was 300 to 350 in 1977, that it was declining, and had been for some time. Whether owing to improved survey methods or to a real change in the size of the population, recent estimates both of indices and of population trend are more encouraging: the smoothed estimate of a conservative population index is 650 animals²; and two decades of research have failed to show any evidence of decline. We conclude from our analysis that the population is *not in imminent danger of extinction* and a status of "Endangered" is not justified.

However, population remains vulnerable, owing to its small size, reduced genetic variability, and exposure to marine traffic and environmental contamination. Additional, and perhaps the most serious, vulnerability factors for these Belugas are their isolation from their conspecifics and their restriction to a small summer range. A suitable status for this population is "*Threatened*": *it may become endangered if the factors that threatened it are not reversed*. Factors, in particular, that are critical are: the size of the population; the rebuilding of populations in Labrador, Hudson Strait and West Greenland; and further improvement in the environmental protection accorded to Beluga habitat in the St Lawrence. We recommend that the status of "Threatened" be accorded, on account of low numbers, low genetic variability, isolation, small area of summer occupancy, and environmental circumstances.

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²Note added in proof: the most recent survey (in August 1997) produced a smoothed index estimate of about 690.

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Status of the Dwarf Sperm Whale, *Kogia simus*, with Special Reference to Canada*

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The Dwarf Sperm Whale, *Kogia simus*, has been recorded in tropical and warm temperate waters world-wide. This species is rarely observed at sea, and little is known of its biology. Insufficient information is available to classify its world-wide status, though they are infrequently taken directly and indirectly in various fisheries. In Canada, the only confirmed record is of a single stranded animal from Vancouver Island, British Columbia, though they are likely found in Canadian waters more frequently. There are no obvious threats to its status in Canadian waters where the species is not at risk.

Le cachalot nain, *Kogia simus*, est répandu dans les eaux tropicales et tempérées chaudes du monde. On observe cette espèce peu souvent en mer et on en connaît très peu sur sa biologie. Il n'y a pas assez d'information pour classer son statut mondial, mais de temps en temps ils sont directement et indirectement attrapés dans les pêches diverses. Il n'y a qu'un seul enregistrement authentique au Canada d'une baleine échouée sur la côte de l'île Vancouver en Colombie-Britannique, bien qu'il soit probable qu'il puisse être plus répandu. Il n'y a aucunes menaces manifestes à son statut dans les eaux canadiennes où l'espèce n'est pas en péril.

Key Words: Dwarf Sperm Whale, Cachalot nain, *Kogia simus*, Physeteridae, status, Canada, Cetacea.

Two species are recognized in the genus *Kogia*, the Pygmy Sperm Whale, *Kogia breviceps* (Blainville 1833), and the Dwarf Sperm Whale, *Kogia simus* (Owen 1866). Little is known about either species. This report summarizes the current state of knowledge of *Kogia simus*, with special reference to its status and management in Canadian waters, by request of the Fish and Marine Mammal Subcommittee of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Description

Sometimes considered as a distinct family Kogiidae (e.g., Nishiwaki 1963; Klinowska 1991), *Kogia* is most commonly recognized under the subfamily Kogiinae within the family Physeteridae (e.g., Handley 1966; Barnes 1973). Numerous scientific names were given to these whales at both the specific and generic level until Hector (1878) encompassed all species under the single name *Kogia breviceps*. Although subsequent works listed more than one species (e.g., Yamada 1954), only a single species was recognized by most authors until Handley's (1966) review of cranial, skeletal, and external characteristics, which confirmed the existence of two species. This nomenclature was further supported by taxonomic comparisons by Ross (1978).

These past taxonomic uncertainties often make it difficult or impossible to accurately determine the

species described in early accounts (e.g., Edmondsun 1948; Manville and Shanahan 1961). As a result, reviews of earlier records for distribution, numerical, and/or other data on either species are often hampered with some degree of uncertainty. Other reports provide sufficient descriptive and/or morphometric details to enable an accurate specific determination to be made (e.g., Schulte (1917), *Kogia breviceps*; Enders (1942), *Kogia breviceps*); such determinations appear in some of the more recent literature (e.g., van Bree and Duguay (1967) in reviewing Weber (1923) — *Kogia simus*; Raun et al. (1970) in reviewing Caldwell et al. (1960) Galveston specimen — *Kogia simus*; Raun et al. (1970) in reviewing Gunter et al. (1955) Mustang Island specimen — *Kogia breviceps*; Aitken (1971) in reviewing Hale (1959) — *Kogia simus*; Gallagher and van Bree (1980) in reviewing Hale (1963) Fremantle specimen — *Kogia simus*; Omura and Takahashi (1981) in reviewing Hirasaka (1937) — *Kogia simus*; Ross (1978) in reviewing Allen (1941) Virginian female — *Kogia simus*; Nagorsen (1985) in reviewing Yamada (1954) — all *Kogia simus*).

Adult Dwarf Sperm Whales range from 2.0 to 2.7 m in length and weigh between 136 and 272 kg (Handley 1966; Ross 1978). Numerous authors have commented on the "shark-like" appearance of *Kogia*, having a squarish head, protruding snout, and a small, narrow underslung jaw ending well posterior to the snout (Figure 1). Body shape is also sometimes described as "porpoise-like", being very robust and tapering rapidly to the tail, which is marked by a median notch between the flukes. A high dolphin-

*Indeterminate status assigned by COSEWIC 16 April 1997.

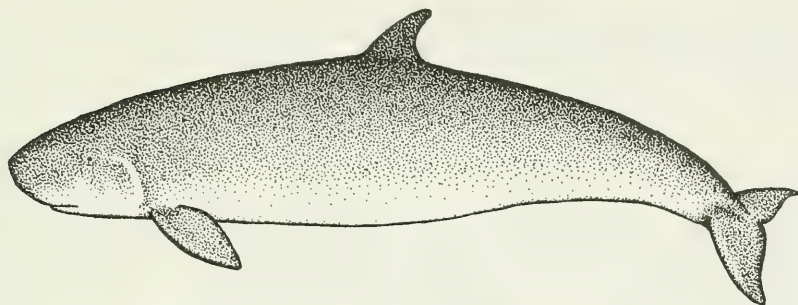


FIGURE 1. Dwarf Sperm Whale. Illustration by Pamela Willis.

like dorsal fin, strongly falcate, is positioned mid-way along the back. The crescentic blowhole is situated slightly left of center in alignment with the eye. The presence of two or more short throat grooves may be characteristic of the species (Leatherwood and Reeves 1983; Leatherwood et al. 1988; Caldwell and Caldwell 1989; Jefferson et al. 1992); however, until examination for this feature becomes standard practice, it will remain unknown whether it is ever absent. Seven to 12 (rarely 13) pairs of thin, sharp, posteriorly-curved teeth, lacking enamel, are present in the lower jaw and up to three pairs may be found in the upper (Handley 1966; Ross 1978). No sexual dimorphism has been reported in either *kogia* species (Handley 1966; Ross 1978). Detailed body measurements are given in Ross (1978) and Chantrapornsy et al. (1991) and are summarized in Nagorsen (1985).

Colouration fades from dark blue-gray or black along the dorsal surface (including the dorsal fin and dorsal surface of the flukes) to a lighter gray along the flanks, broken only by the dark gray dorsal surface of the pectoral flippers, fading to dull white or pink on the ventral surface. A pale crescent or bracket-shaped mark (often termed "false gill" or "bracket mark"), appears between the eye and insertion of the flipper and appears to be characteristic of the genus (Hubbs 1951; Yamada 1954; Ross 1978). A second lightly-pigmented process ascending just anterior to the bracket mark has been observed on some Dwarf Sperm Whales, creating a dark "island" between the two marks (Yamada 1954). Rarely described, this feature is apparent in some photographs of stranded individuals (e.g., Leatherwood et al. 1988, Figure 252, Japan specimen; Caldwell and Caldwell 1989, Figure 4(C), Florida specimen). Variability among individuals is also apparent in the degree of extension of white ventral colouration up into a ridge or "island" just anterior to the eye (Yamada 1954).

The *Kogia* skeleton exhibits a number of unique characteristics. The skull has the shortest (proportionally) rostrum among extant cetaceans, it lacks an independent jugal, has a pronounced supracranial

basin and sagittal septum, and is asymmetrical, having a left naris considerably larger than the right (Handley 1966; Nagorsen 1985). All cervical vertebrae are fused together, the costal cartilages are unossified, the sternum is reduced to three elements, and the scapula is low and porpoise-like (Handley 1966; Nagorsen 1985). Vertebral counts of the Dwarf Sperm Whale vary from 50 to 57 (cervical = 7, thoracic = 12 - 14, lumbar-caudal = 29, 35-37) (Owen 1866; Allen 1941; Yamada 1954; Hale 1959; Pinedo 1987). Nagorsen (1985), in reviewing vertebral and rib counts by several authors, states that it is not clear whether these different counts reflect individual variation or a loss of bones during preparation of the skeleton. The small nature of the terminal vertebrae of *Kogia* has been noted by several authors (e.g., Allen 1941; Hale 1962), and Allen (1941) states that these are easily lost and that caudal counts for the majority of his specimens are subject to error. If the lower counts are indeed due to incomplete skeletal preparation, then differences in vertebral count between the two species of *Kogia* may become apparent with the acquisition of new specimens, as has been proposed by Omura et al. (1984). A phalangeal formula of I 2, II 5, III 4, IV 4, and V 2 was given by Owen (1866). Hyoid apparatus anatomy and function is reported by Reidenberg and Laitman (1994). Detailed descriptions of the skull and/or skeleton are provided by Owen (1866), Hirasaka (1937), Yamada (1954), Ross (1978), Gallagher and van Bree (1980) and Nagorsen (1985).

Several characters to distinguish between the two species have been described since Handley's (1966) synopsis (Table 1). Height and position of the dorsal fin are the most common diagnostic features used in species determination, particularly from photographs or measurements (e.g., Raun et al. 1970; Robineau and Rancurel 1981; Sylvestre 1988a), although Sylvestre (1988a) questions the reliability of these characters, and Ross (1978) states that caution should be used in using the latter due to the relatively small differences in the posi-

TABLE 1. Distinguishable, partially distinguishable, and potentially distinguishable characteristics of *Kogia simus* and *Kogia breviceps*. Measurements apply to adult specimens, other characters apply regardless of age. Modified from (A) Handley 1966, (B) Ross 1978, (C) Leatherwood and Reeves 1983, (D) Omura et al. 1984, (E) Leatherwood et al. 1988, and (F) Jefferson et al. 1992.

Character	<i>Kogia simus</i>	<i>Kogia breviceps</i>	Source(s)
<i>Distinguishing Characters</i>			
Total Length	≤2.7 m	>2.7 m	A, B
Weight	136-272 kg	318-408 kg	A
Dorsal Fin	high (>5% TL), near center, anterior insertion generally <50% TL	low (<5% TL), posterior to back, anterior insertion >50% TL	A, B
Mandibular Teeth	7-12 (rarely 13) pairs	12-16 (rarely 10 or 11) pairs	A, B
Maxillary Teeth	0-3 pairs	none	A, B
Condylbasal Length	<323 mm	>333 mm	A, B
Mandibular Symphysis	short (<51 mm) and ventrally level	long (>64 mm) and ventrally keeled	A, B
Dorsal Cranial Fossae	cupped posteriorly and sub-symmetrical	not cupped posteriorly; left fossa longer and narrower than right; elongated	A, B
Dorsal Sagittal Septum (near vertex)	least breadth generally <20 mm; narrow, near-vertical walls, often pinched posteriorly	least breadth >20mm; broad, slopes gradually into cranial fossae	A, B
Snout Length (tip to blowhole)	7.5-10.1% of total length	10.4-12.8% of total length	B
<i>Partially Distinguishing Characters</i>			
Tooth Length, Diameter	shorter, proportionally more slender than <i>Kogia breviceps</i> . Unlikely to exceed 30 mm length, 4.5 mm diameter. Teeth 20-30 mm long generally have >60% pulp cavity closure	longer, proportionally wider than <i>Kogia simus</i> . May exceed 30 mm in length, 4.5 mm diameter. Teeth 20-30 mm long have <60% pulp cavity closure	B
<i>Potentially Distinguishing Characters</i>			
Throat Grooves	2 or more	none	C, E, F
Vertebral Number	55-57	52-54	D

tion of anterior insertion. Ross (1978) also detected overlap between the two species in the position of the foramen magnum relative to skull height, precluding this feature as a distinguishing character as stated by Handley (1966). Anatomical differences between the two species are described by Yamada (1954), Handley (1966), and Ross (1978).

Like the Sperm Whale (*Physeter macrocephalus*), *Kogia* have a spermaceti organ associated with the right, smaller diameter, naris, situated between the narial passages and posterior to the large fatty melon. Nasal tract and spermaceti organ structure is described by Schenckan and Purves (1973). Melon and blubber lipid composition is described in Litchfield and Greenberg (1974), Litchfield et al. (1975), and Karol et al. (1978).

A structure apparently unique to *Kogia* is a sac which expands from the lower intestine near the anus, filled with a dense, dark, reddish-brown fluid resembling chocolate syrup (Benham 1901; Caldwell and Caldwell 1989). *Kogia* appear to release the fluid, which produces a dense red cloud in the water,

when stressed (Yamada 1954; Scott and Cordaro 1987; Caldwell and Caldwell 1989) (see *Behaviour* under **General Biology**, below).

A detailed description of Dwarf Sperm Whale anatomy is provided by Ross (1978). Detailed anatomy of a *Kogia* sp. (not easily determinable to species due to characters shared by both) is provided by Benham (1901). No anatomical observations appear to be available on fetal *Kogia simus*, although Kernan and Schulte (1918) and Schulte and Smith (1918) provide anatomical details of a fetal *Kogia breviceps*.

Distribution

Knowledge of the distribution of both *Kogia* species is imprecise, as it is derived largely from stranded specimens. Sightings of *Kogia* at sea for which species identifications are made occur infrequently. It has been suggested that there may be no reliable characters with which the species may be distinguished at sea (Leatherwood and Reeves 1983; Leatherwood et al. 1988); recent sighting records

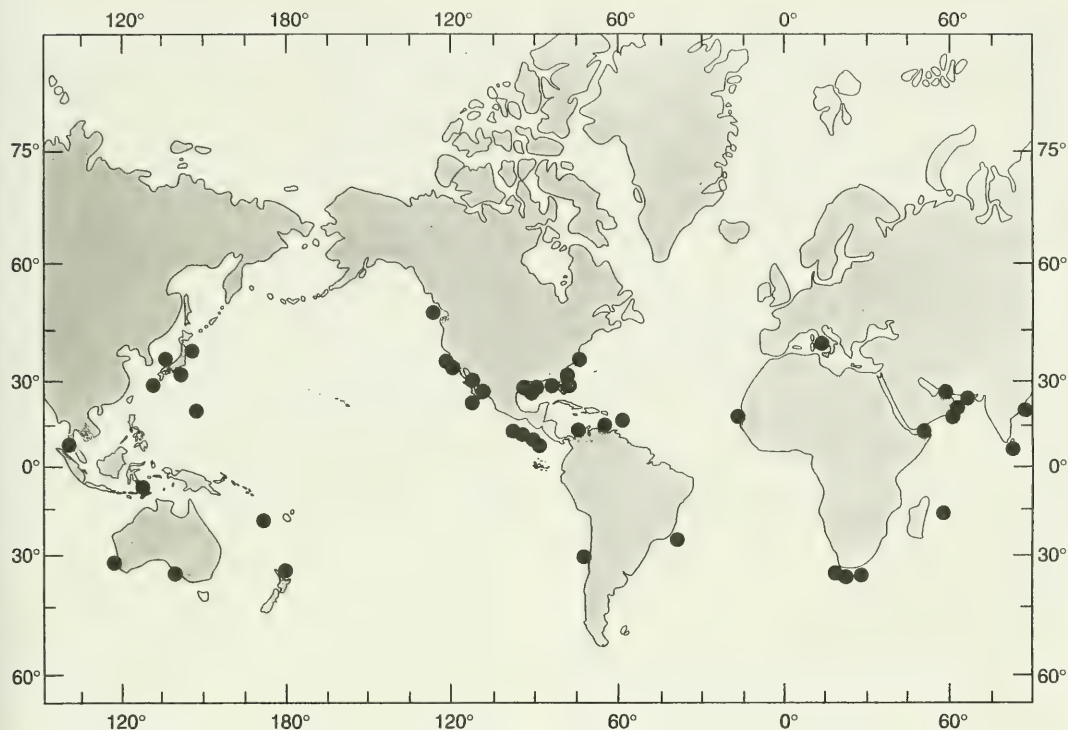


FIGURE 2. General localities of *Kogia simus* records based primarily on stranding and catch data. Each symbol represents one or more record or non-specific locality. (Modified after Nagorsen 1985: Figure 5; and Caldwell and Caldwell 1989: Figure 2.)

indicate that in some instances differentiation is possible (e.g., Wade and Gerrodette 1993). Their consideration as a single species until fairly recently makes precise range determination additionally problematic.

Both species occur in tropical and temperate waters world-wide, with the Dwarf Sperm Whale potentially preferring slightly warmer waters (Caldwell and Caldwell 1989) (Figure 2). In the North Pacific, records of *Kogia simus* have been obtained from Guam, Mariana Islands (Kami and Lujan 1976), Japan (Hirasaka 1937; Yamada 1954; Sylvestre 1988a), Vancouver Island, Canada (Nagorsen and Stewart 1983), California, United States (Roest 1970; Jones 1981), Mexico (Rice 1978) including the Gulf of California (Aurioles et al. 1993; Breese and Tershy 1993), and off Central America (Scott and Cordaro 1987). South Pacific records include New Caledonia (Robineau and Rancurel 1981), New Zealand (Brabyn 1991) and off central Chile (Crovetto and Toro 1983). Ninety-five sightings of Dwarf Sperm Whales were recorded south of 24°N during surveys in the Eastern Tropical Pacific (ETP) (Wade and Gerrodette 1993). Western North Atlantic and Gulf of Mexico stranding records include Virginia (Allen 1941), Florida

(Zam et al. 1971; Odell et al. 1985; Candela 1987), Georgia (Caldwell et al. 1971; Candela 1987), Louisiana (Jefferson 1995), and Texas (Caldwell et al. 1960; Jefferson 1995) in the United States. No records appear to exist from eastern Canada. Sightings within the continental slope region of north-central Gulf of Mexico are provided in Mullin et al. (1991) and Jefferson (1995) provides a historical review of Gulf of Mexico sightings and strandings. Caribbean records include St. Vincent Island (Caldwell et al. 1973), Colombia (Vidal and Findley 1989), and the Netherlands Antilles (Debrot and Barros 1992). The only eastern North Atlantic records consists of a single stranding off Senegal, Africa (Maigret and Robineau 1981). A single individual stranded in the Mediterranean off Italy (Baccetti et al. 1991). The only published record from the South Atlantic is of a stranding in southern Brazil (Pinedo 1987). Indian Ocean specimens have been reported from Oman (Gallagher and van Bree 1980; Gallagher 1991), Pakistan (de Silva 1987), India (Owen 1866), Sri Lanka (Leatherwood 1985; Leatherwood and Reeves 1989; see review by de Silva 1987), Thailand (Chantrapornsy et al. 1991), Indonesia (Weber 1923), western Australia (Hale 1963), and South Africa (Ross 1978; Klages et al.

1989), and are summarized in Chantrapornsy et al. (1991). A Southern Ocean record of two stranded Dwarf Sperm Whales is from near Adelaide, South Australia (Hale 1959). The relative paucity of eastern and South Atlantic records may reflect a lack of observer effort (Gunter et al. 1955; Ross 1978; Caldwell and Caldwell 1989).

Protection

International

The Dwarf Sperm Whale is listed under Appendix II of the Convention on International Trade in Endangered Species of Wild Fauna and Flora 1973 (CITES) (see Birnie 1982). This listing regulates the international trade of listed species and products derived from them between members and non-members of the convention via an export permitting system. At present there does not appear to be any international trade in Dwarf Sperm Whale products. The International Whaling Commission (IWC) regulates the taking of whales in accordance with the current Schedule provisions; however, due to a lack of consensus on behalf of the members of the Commission, it is unclear whether "whale" refers to all cetaceans or only certain species (Klinowska 1987, 1991), so coverage of the Dwarf Sperm Whale under the Commission's mandate is a matter of debate.

National

Canada: Until they were repealed in 1993, the Cetacean Protection Regulations of the Fisheries Act of Canada of 1867 protected all cetacean species from "hunting". "Hunting" was defined as "to chase, shoot at, harpoon, take, kill, attempt to take or kill, or to harass cetaceans in any manner", and could only be taken under licence. Aboriginal "hunting"; however, could be undertaken without licences. The Cetacean Protection Regulations were replaced with the Marine Mammal Regulations of the Fisheries Act in early 1993. These regulations appear to provide no more or no less protection, by stating only that "no person should disturb a marine mammal except when...under the authority of these Regulations". No provisions exist for regulation of incidental catches in fishing operations. Canada is not currently a member of the IWC, having withdrawn in 1982 (IWC 1982).

United States: All cetaceans are protected through the Marine Mammal Protection Act of 1972 (as amended to date), as well as through the Packwood-Magnuson Amendment of the Fisheries and Conservation Act and the Pelly Amendment of the Fisherman's Protective Act.

Population Size(s) and Trends

There is insufficient information to accurately classify the world status of the Dwarf Sperm Whale (Klinowska 1991). World-wide population size of either species of *Kogia* is unknown. The only abun-

dance estimate of *Kogia simus* is 11 200 (CV = 0.294, upper and lower 95% bootstrap CL = 7700, 16 200) for the ETP; this is likely an underestimate, possibly by as much as one half (Wade and Gerrodette 1993).

Although sometimes reported as rare (e.g., Handley 1966; Sylvestre 1983), several authors have noted that *Kogia* are difficult to detect and are likely much more common than sighting records would suggest (Caldwell and Caldwell 1989; Chantrapornsy et al. 1991; Jefferson et al. 1992). Au and Pitman (1988), using 20 and 25 power binoculars, noted the difficulty in seeing *Kogia* in other than calm sea conditions during biological surveys in the ETP. The subtle surface behaviour, deep water distribution, small group size and at least occasional skittishness (see *Behaviour* under **General Biology**, below) of both species likely give an erroneous impression of rarity (Enders 1942; Jefferson et al. 1992; Baird unpublished data).

There is no information available on stock identity. No detailed study on geographic variation in either species has been undertaken. Yamada (1954) states that there are pigmentation differences between Japanese *kogiids* and those from American coasts; however, the occurrence of a Dwarf Sperm Whale from Florida with pigmentation similar to those described by Yamada (see Caldwell and Caldwell 1989, Figure 4C) demonstrates that such marking is not limited to Japanese specimens.

Habitat

Dwarf Sperm Whales inhabit deep waters in temperate and tropical regions; although typically offshore, sighting records from nearshore areas in the southwestern Gulf of California exist (Aurioles et al. 1993; Baird unpublished data). Identification of prey species (mainly squid) obtained from the stomachs of stranded individuals from various areas suggest that the Dwarf Sperm Whale occurs primarily along the continental shelf and slope in the epi- and meso-pelagic zones (Fitch and Brownell 1968; Ross 1978; Candela 1987; Klages et al. 1989). Although the diets of both *Kogia* species overlap, the relative contribution of prey types suggests that *Kogia simus* occurs farther inshore than *Kogia breviceps*, with the former foraging upon smaller squid and shallower depths than the latter (Ross 1978; Candela 1987; Klages et al. 1989; Aurioles et al. 1993). Ross (1984) suggested that younger animals utilize the outer section of the shelf and upper portion of the slope, while adults occur in deeper waters.

General Biology

Reproduction/Life History

Based on examinations of corpora activity and analysis of length data of females with fetuses or small calves, Ross (1978, 1984) identified several

sexually mature females and estimated a length at sexual maturity of between 210 - 220 cm. Bossart et al.'s (1985) and Caldwell and Caldwell's (1989) subsequent examinations of ovary activity in two and one other females, respectively, agree with Ross' estimate. Six males examined by Ross (1978) were identified as sexually mature based on testes dimension, tubule diameter, and presence of sperm. Published data on four other males led Ross (1978) to suggest a length at sexual maturity of between 210 - 220 cm; 210 cm was also the minimum length at male sexual maturity found by Bossart et al. (1985), based on evidence of spermatogenesis, and is supported by Caldwell and Caldwell's (1989) examination of testes and sperm production in three males. Based on the extent of fusion of vertebral epiphyses to the bodies of the centra in both his sample specimens and those from the literature, Ross (1978; 1984) found length at physical maturity to vary considerably between individuals, occurring between 210 - 270 cm. Age at sexual maturity is unknown; Ross (1978) attempted aging Dwarf Sperm Whales based on tooth growth layers but was unsuccessful as growth increments form more than once annually, and groups of increments did not cluster in a manner suggestive of annual increments. Longevity is unknown. Comparisons of calf and fetal lengths led Ross (1978) and Pinedo (1987) to estimate length at birth at 1 m. Observations of pregnant females with calves in both species of *Kogia* suggest that females may become pregnant in successive breeding seasons (Allen 1941; Ross 1978). Pinedo (1987) lists records of fetal and juvenile Dwarf Sperm Whales, and plots Southern Hemisphere records of body length against date, suggesting that mating occurs in summer and birthing in early summer. She estimates a gestation period of about 9.5 months. Comparisons of calf lengths versus time of year suggest that the calving season may last over five months (Ross 1978; Nagorsen 1985; Chantrapornsy et al. 1991). Using data provided by Ross (1978) and Caldwell and Caldwell (1989), measurements of testes from sexually mature males yielded variable lengths ranging between 9.8 - 22.2 % total body length. The nine mature males and eight mature females recorded as strandings led Ross (1978) to suggest a sex ratio approximating 1:1, assuming each sex demonstrates equal longevity and probability of stranding. Detailed descriptions of the gonads may be found in Ross (1978).

Movements

Seasonal differences in stranding records for certain areas have led numerous authors to suggest the possibility of seasonal movements (e.g., Allen 1941; Gunter et al. 1955; Sylvestre 1988b) however, no conclusive evidence is available due to small sample sizes, actual or potential biases in effort, and other

potential seasonal influences (e.g., weather). Odell et al. (1985) observed that the stranding seasonality of *Kogia* in Florida followed the annual inshore/off-shore signal of the Gulf Stream, with the number of strandings increasing as the stream moves farther offshore. They suggest that individuals may follow prey into short-term meanders of the stream over the shelf but are unable to return to familiar waters once the meanders dissipate. A review of Sri Lankan catch records by Chantrapornsy et al. (1991) revealed increased catches in the summer months, which they suggest may be a reflection of increased fishing effort; a summer increase in catches off Japan was attributed to migratory movements by Yamada (1954); however, no information on seasonal distribution of fishing effort was provided. No seasonal differences are apparent for the Gulf of Mexico (Jefferson 1995), the southwest Gulf of California (Aurioles et al. 1993; Baird, unpublished data), or South Africa (Ross 1978).

Feeding

The most commonly recorded prey of Dwarf Sperm Whales are cephalopods. Remains (primarily beaks) have been recovered from stranded animals from Japan (Fitch and Brownell 1968), western Canada (Nagorsen and Stewart 1983), California (Jones 1981), Florida, Georgia (Candela 1987), western Africa (Maigret and Robineau 1981), South Africa (Ross 1978; Klages et al. 1989), and southern Brazil (Pinedo 1987). Identified cephalopod prey include members of the families Histioteuthidae, Enoploteuthidae, Gonatidae, Lycoteuthidae, Cranchiidae, Octopoteuthidae, Chiroteuthidae, Onychoteuthidae, Ommastrephidae, Mastigoteuthidae, Brachioteuthidae, Loliginidae, Vampyroteuthidae, Sepiidae, and Octopodidae (Ross 1978; Jones 1981; Nagorsen and Stewart 1983; Candela 1987; Pinedo 1987). Ross (1978) examined stomach contents of 24 Dwarf Sperm Whales, all of which stranded prior to 1976 in South Africa, and found sepiids to be the most common prey type; whereas Klages et al. (1989) found *Lycoteuthis* and *Histioteuthis* to be the most common prey taken between 1975 and 1987 in their analysis of 33 *Kogia simus* stomach contents. Enoploteuthids were the most abundant prey in animals from Florida and Georgia, followed by histioteuthids, ommastrephids, and loliginids (Candela 1987). *Histoteuthis atlantica* and *Histoteuthis macrohista* predominated the beaks found in a specimen from southern Brazil (Pinedo 1987). *Loligo vulgaris* and *Octopoteuthis* sp. were significant prey species on the eastern African coast but insignificant in the south and west (Klages et al. 1989). Fish are represented less often in stomach contents. Fitch and Brownell (1968) provide a detailed species list of otoliths taken from three Dwarf Sperm Whales off Japan, representing 18 species from seven families (Argentinidae,

Congridae, Gonostomatidae, Macrouridae, Moridae, Myctophidae and Sternoptychidae). Otoliths and jaws of several fish species were recorded by Ross (1978) (*Photichthys argenteus*, *Chauliodus* sp., *Stomias boa*, an unidentified gempylid, *Nansenia* sp., *Melamphaes* sp., *Benthodesmus* sp., *Sudis* cf. *hyalina*, stomiatoids cf. *Chauliodus*, a possible macrourid, *Lampanyctus* spp., *Myctophum* spp. *Scopelopsis multipunctatus*, and several unidentified myctophids), and a single pair of *Porichthys* sp. otoliths were found in a Brazilian specimen (Pinedo 1987). Other occasional prey include crustaceans such as shrimp and crab (Fitch and Brownell 1968; Ross 1978; Maigret and Robineau 1981; Nagorsen and Stewart 1983; Pinedo 1987; Klages et al. 1989). Analysis of the hyoid apparatus in all the Physteridae indicate powerful suction feeding (Reidenberg and Laitman 1994).

Analysis of prey items suggests that feeding occurs at a range of depths. The stomachs of two Dwarf Sperm Whales off Senegal, West Africa, contained shrimp which typically occur between 500 - 1300 m (Maigret and Robineau 1981). Examination of prey items of three specimens from Japanese waters indicated habitual feeding at depths greater than 250 m; 3 species of bottom-dwelling fish (Macrouridae), which are typically found in waters 450 - 1500 m deep, were present in all three specimens (Fitch and Brownell 1968). The majority of squid prey found in South African *Kogia simus* were sepiids (Ross 1978), which typically occur within 100 m of the surface (Roeleveld 1972), and in other animals benthic fish and crab have been identified (e.g., Jones 1981), indicative of bottom feeding (Gaskin 1982).

Behaviour

Observations of wild *Kogia* suggest they typically form small groups of one to four, with occasional groups of up to ten reported (Palmer 1948; Yamada 1954; Handley 1966; Ross 1984; Au and Pitman 1988). Wade and Gerrodette (1993) calculated a Dwarf Sperm Whale mean group size of 1.7 (coefficient of variation = 0.07) during marine mammal surveys in the ETP, and Au and Pitman (1988) calculated a mean group size of 2, standard deviation = 1, based on 30 observations of unidentified *Kogia* during surveys in the same region.

The surface behaviour of *Kogia* is poorly known due to the paucity of sightings. Both species appear to be slow-moving, rarely engaging in rapid or boisterous surface activity (Allen 1941; Handley 1966). They are typically observed floating at the surface with the back of the head and anterior dorsal surface exposed, much in the same manner as sperm whales (Yamada 1954; Leatherwood and Reeves 1983; Caldwell and Caldwell 1989; Breese and Tershy 1993). Usually all or some of the dorsal fin is exposed as well (Baird, personal observation).

The blow of both species is rarely visible, and upon diving, *Kogia* typically sink vertically, rather than rolling at the surface and exposing the tail stock (Leatherwood et al. 1988; Baird, personal observation). Surface behaviour of *Kogia simus* and/or unidentified *Kogia* in recent surveys in the Gulf of California typically consisted of continuous resting at the surface for approximately one minute (J. Barlow, Southwest Fisheries Science Centre, P.O. Box 271, La Jolla, California 92038, personal communication). The animals would then simply disappear, but would often reappear after a very brief dive (less than three minutes) for another similar period of surface resting.

Allen (1941), Palmer (1948), and Yamada (1954) all mention accounts describing the ease with which *Kogia* could be harpooned, being quite approachable. Such records have presumably led to descriptions such as "easy to approach" (Katona et al. 1993; referring to *Kogia breviceps*) and "apparently oblivious to approaching vessels" (Caldwell and Caldwell 1989; referring to both species). Whalers in the Lesser Antilles, however, describe *Kogia* as being elusive and wary, being difficult to approach and catch (Reeves 1988). Similarly, one of us (RWB) found Dwarf Sperm Whales difficult to approach in the southwestern Gulf of California, frequently observing them through binoculars but rarely being able to approach within 200 m. Records of cetacean responses to survey platforms recorded in the north-central and western Gulf of Mexico showed *Kogia* to respond negatively to the ship (73%, 11/15 sightings) and to change their behaviour in response to the survey airplane in 40% (12/30) of sightings (Lynn et al. 1995). Recent observations of *Kogia simus* and/or unidentified *Kogia* in the Gulf of California also found them to be difficult to approach, both with a large ship and out-board launches (J. Barlow, personal communication). The fact that they are rarely sighted may result in part due to a general inapproachability, whereby animals may descend beneath the surface in response to an approaching vessel before being detected. The difficulty with which *Kogia* are observed at sea suggests that a close approach is likely often necessary before the unaided eye can detect them. Even with the advantage of binoculars, detection can be difficult in other than calm sea conditions (e.g., Au and Pitman 1988). More observations at sea are required before the approachability of either species can be accurately determined.

Breese and Tershy (1993) recorded four dive times for a Dwarf Sperm Whale in the central Gulf of California to the nearest minute: 14, 43, 19 and 30. A recent survey in the Gulf of California recorded 59 dive intervals of *Kogia simus* and/or unidentified *Kogia* (J. Barlow, personal communication). The median dive time was 8.6 minutes and the median surface time was 1.2 minutes, but

dives of up to 25 minutes and surface periods of up to three minutes were fairly common. Longer dive times (up to 53 minutes) were recorded but were probably the result of one or more missed surfacings.

Analysis of lung volume and mechanics of a stranded *Kogia breviceps* suggested capability of high expiratory flow rates at reduced lung volume, which may function to prevent decompression sickness (Berger 1983); similar form and function may occur in *Kogia simus*. Examination of the structure and function of the eye in *Kogia simus* suggests capability in low light such as would occur at depth (Dawson 1980).

Associations with other species of marine mammals or with seabirds appear to be extremely infrequent; we could find no such records in the literature. Groups of *Kogia* were observed 30 times during biological surveys in the ETP, none of which involved seabird associations (Au and Pitman 1988). In the ETP, two *Kogia simus*, presumed to be mother and calf, were accidentally encircled in a purse seine net set for Yellowfin Tuna (*Thunnus albacares*) associated with Spotted Dolphins (*Stenella attenuata*) and Spinner Dolphins (*Stenella longirostris*), but at no time prior to or during the set did they appear to be associated with the dolphins (Scott and Cordaro 1987). About 30 observations of Dwarf Sperm Whales in the southern Gulf of California revealed no evidence of seabird or other associations (Baird, unpublished data).

As noted, *Kogia* expel a reddish-brown cloud of fluid from the anus when apparently disturbed or threatened (Yamada 1954; Scott and Cordaro 1987; Caldwell and Caldwell 1989; Aurioles et al. 1993). Both stranded animals and *Kogia* caught in fishery operations have been observed to engage in this behaviour, often termed a "startle response", which may serve to temporarily conceal the animals or operate as a decoy (Scott and Cordaro 1987). The cloud produced may cover an area of 100 square meters (Scott and Cordaro 1987), and is often interpreted as feces or blood (Yamada 1954; Caldwell and Caldwell 1989).

We found nothing published on sounds produced by *Kogia simus*. Observations of captive animals suggest that neither species is particularly vocal (Caldwell and Caldwell 1989; Thomas et al. 1990). Recent attempts at recording Dwarf Sperm Whale sounds in the Gulf of California confirm these impressions (Steve Dawson, personal communication). Thomas et al. (1990) recorded a low frequency "cry" from a captive *Kogia breviceps* and echolocation signals have also been recorded from captive *Kogia breviceps* (Caldwell et al. 1966; Caldwell and Caldwell 1987). Caldwell and Caldwell (1989) suggest that similar sounds are likely produced by *Kogia simus*.

Limiting Factors

Data on natural mortality are scarce. *Kogia breviceps* has been preyed upon by Killer Whales (*Orcinus orca*) off St. Vincent, Caribbean, as has *Kogia* (not identified to species) in the Indian Ocean (Perrin 1982). Substantial scarring on some stranded Dwarf Sperm Whales is suggestive of shark attacks (Caldwell and Caldwell 1989), and scars attributed to the White Shark (*Carcharodon carcharias*) were found on a stranded *Kogia breviceps* in northern California (Long 1991). A variety of internal parasites have been recorded from stranded *K. simus*, but none have been positively linked to mortality (c.f. Roest 1970; Zam et al. 1971; Ross 1978; Caldwell and Caldwell 1989). Myocardium lesions and hepatic change consistent with heart failure was found in several stranded adult *Kogia* of both species (Bossart et al. 1985). Pneumonia has also been observed in stranded *Kogia* (Caldwell and Caldwell 1989). To the authors' knowledge no toxicology studies have been carried out on *Kogia simus*; analysis of heavy metals in an Argentinian *Kogia breviceps* revealed high cadmium concentration relative to other marine mammals studied (Marcovecchio et al. 1990; Marcovecchio et al. 1994), but it is unknown what role such elevated levels may have in mortality.

Kogia are infrequently taken by fisheries, both as direct catches and as bycatch. Both species have been killed accidentally in Sri Lanka (Leatherwood 1985; Leatherwood and Reeves 1989), and both directly and incidentally in Japanese fisheries (Yamada 1954; Handley 1966; Fitch and Brownell 1968; Omura et al. 1984; Sylvestre 1988a). *Kogia simus* and unidentified *Kogia* have been occasionally deliberately killed in small whaling operations in the Lesser Antilles (Caldwell et al. 1973; Reeves 1988), and probably still are (Reeves 1988). *Kogia* have been hunted in Indonesia (Weber 1923) but there is no evidence of takes in recent years (Barnes 1991). Two Dwarf Sperm Whales were incidentally encircled in a tuna purse seine set in the ETP (Scott and Cordaro 1987). Two *Kogia* were taken by fishermen in Hawaii, one by spearing and one taken by baited hand line (Edmondson 1948); kangaroo ligaments were found in the stomach of a South Australian specimen, presumably taken as fisherman's bait (Hale 1962).

Ingestion of plastic items could potentially lead to intestinal blockage. Plastic items have been found in the digestive tracts of both species; a Dwarf Sperm Whale stranded off Senegal, West Africa had part of a ball-point pen in the latter portion of the intestine, apparently present for some time (Maigret and Robineau 1981), and Ross (1978) found a plastic bag in the stomach of a South African specimen. A young male *Kogia breviceps* stranded in Texas had a plastic garbage can

liner, a bread wrapper, a chip bag, and two additional pieces of plastic in its forestomach and fundic stomach (Tarpley and Marwitz 1993). Caldwell and Caldwell (1989) suggest that plastic may resemble squid and be mistakenly consumed. Allen (1941) states that wounds apparent on an adult female *Kogia simus* and a presumed yearling male stranded south of Cape Henry, Virginia, resulted from propeller collisions. Caldwell and Caldwell (1989) suggest that a few *Kogia* are likely injured or killed from boat collisions; however, such events are probably very rare.

Special Significance of the Species

There is insufficient information to accurately classify the world status of the Dwarf Sperm Whale (Klinowska 1991). The world status of the other member of the genus, the Pygmy Sperm Whale, is also poorly known.

Evaluation

Only one record of this species exists from Canadian waters. With the difficulty of spotting this species at sea, individuals may be regularly occurring in some areas off Canada's coasts but is likely rare or uncommon at best. No serious threats to its status in Canadian waters are apparent, but there is insufficient scientific information on which to base a COSEWIC status designation.

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Note added in proof

A record of this species from eastern Canada is mentioned in Lucas and Hooker (1997). On 30 September 1996 a 226 cm long male *Kogia simus* was found dead on the south beach of Sable Island, off Nova Scotia (approximately 44°N, 60W). Photos measurements, and tissue samples from this animal were collected (Lucas and Hooker 1997), and details will be presented by Lucas et al. (in preparation).

Lucas, Z. N., and S. K. Hooker. 1997. Cetacean standings on Sable Island, Nova Scotia 1990–1996, Paper SC/49/06 presented to the International Whaling Commission Scientific Committee.

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Status of the Cultus Pygmy Sculpin, *Cottus* sp., in Canada*

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Coffie, P. A. 1998. Status of the Cultus Pygmy Sculpin, *Cottus* sp., in Canada. *Canadian Field-Naturalist* 112(1): 126-129.

The Cultus Pygmy Sculpin, *Cottus* sp., is a limnetic population of minute cottids that has apparently evolved from *Cottus aleuticus*. The form is known to occur only in the deep waters of Cultus Lake in the Fraser River watershed of southwestern British Columbia. Almost no information is available on this fish; no threats to the population are evident except for the inherent risk of the restricted distribution.

Le Chabot pygmé Cultus, *Cottus* sp., est une population limnétique de cottidés minuscules qui a apparemment évolué de *Cottus aleuticus*. Jusqu'à ici, cette forme est seulement dans les eaux profondes du lac Cultus dans le bassin de la rivière Fraser au sud-ouest de la Colombie-Britannique. Peu d'information est disponible sur cette espèce; aucunes menaces existent contre la population sauf le risque inhérent à la répartition limitée.

Key Words: Cultus Pygmy Sculpin, Le Chabot pygmé Cultus, *Cottus* sp., British Columbia, endangered species.

The Cultus Pygmy Sculpin, (*Cottus* sp.), is only found in Cultus Lake, in the Fraser River watershed of southwestern British Columbia. The form is endemic to Canada, although a similar fish is found in Lake Washington, near Seattle, Washington (Larson and Brown 1975; McPhail and Lindsey 1986). These two forms are believed to have evolved independently; a case of independent parallel evolution (see Cannings 1993). Both forms are derived from the Coast Range Sculpin (*Cottus aleuticus*, Gilbert 1985), a widespread species that occurs in Pacific coastal streams from central California northward to Kiska Island and the Kobuk River, Alaska (Scott and Crossman 1973; Wallace 1980).

Although mentioned in Scott and Crossman's (1973) discussion on *Cottus aleuticus*, the only known study of the Cultus Pygmy Sculpin is that of Ricker (1960). Given a global rank of G1 and a provincial rank of S1 by the Conservation Data Centre/Nature Conservancy ranking system and a provincial listing as Red (see Cannings 1993: 2-6), this is a species of concern, not previously considered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This report was undertaken to provide a synopsis of the available information for possible status determination.

Description

The cottids are a distinctive scorpaeniform group of perciformes-like fishes and many of the morphological traits reflect the bottom-living habits which are characteristic of the cottidae. The sculpins are large-headed, heavy-bodied fishes with large pectoral fins. The body tapers from the head to a relatively narrow

caudal peduncle. There is a spiny fin and a soft dorsal fin and one or more spines on the preopercule (McPhail and Lindsey 1970). Primarily marine fishes of arctic and temperate seas, species in the genus are widely distributed in fresh waters of the Northern Hemisphere. There are eight species in Canadian fresh waters, six of which are found in British Columbia (Scott and Crossman 1973). The freshwater species are usually small fish, seldom exceeding 18 cm in total length, although the Prickly Sculpin, *Cottus asper*, may reach lengths of up to 31 cm.

There appears to be no recorded description of the Cultus Lake form except that of Ricker (1960), and the original application of the common name is not known, except that it is known only from Cultus Lake, but it appears to have become accepted locally (Peden 1990; McPhail and Carveth 1992; Cannings 1993). The parent form, *Cottus aleuticus* (Figure 1), is typical of the genus with a broad heavy head, decreasing in size posteriorly to a moderately deep laterally depressed caudal peduncle. The elongated body averages 7.6 to 10.2 cm Total Length (TL) [Scott and Crossman 1973]. There is a well developed preopercular spine and the preoperculo-mandibular pore count is 10-1-10, one pore being on the tip of the chin. The pectoral fins are large and fan like with 15 to 16 rays, the pelvic fins are small with one spine and 4 soft rays. There are two dorsal fins, the first with eight to ten spines, the second larger with 16 to 20 soft rays. The caudal fin is slightly rounded; the anal fin is long with 12 to 16 rays. There are no typical scales but small prickles remain behind each pectoral fin. The lateral line is complete and has 30 to 44 pores (Scott and Crossman 1973).

The fish (*Cottus aleuticus*) are brown to grey with darker blotches, being lighter on the sides and almost white ventrally. There are usually two or three dark

*Vulnerable status assigned by COSEWIC 16 April 1997.

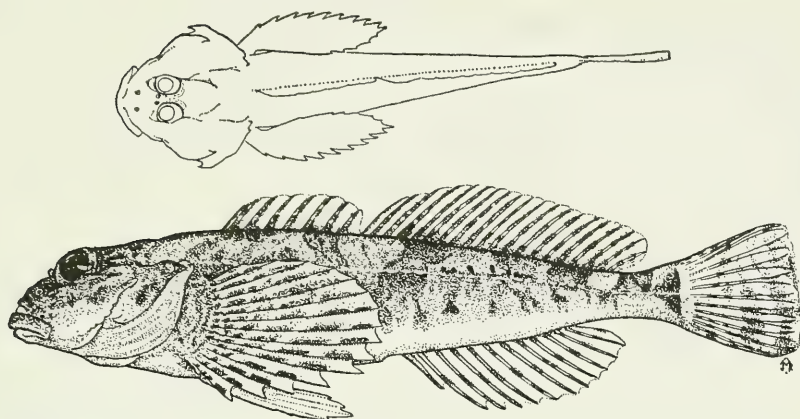


FIGURE 1. Coast Range Sculpin, *Cottus aleuticus*, (from McPhail and Lindsey 1970, by permission). The Cultus Lake form (no illustration available) is smaller (5 cm as opposed to 7 to 10 cm) with large pores on the head.

saddle-like blotches on the sides under the second dorsal fin. The fins are pigmented, usually in the form of bars. Young fish lack pigmentation on the fins and spawning males are generally darker in colour with an orange band on the edge of the first dorsal fin (Scott and Crossman 1973).

Apparently the morphology of the Cultus Lake limnetic form is significantly altered from the parent form, *Cottus aleuticus*. The fish are considerably smaller, resembling larvae, with a maximum length of 50 mm, the density of the bone is reduced, subcutaneous lipids are increased and there are large pores on the head (Ricker 1960; Cannings 1993). McPhail (as communicated to Cannings 1993) believes this form to be an example of neotenic evolution. As indicated by Larson and Brown (1975) with the Lake Washington forms, any decision as to specific status has to be deferred until the degree of reproductive isolation from *Cottus aleuticus* is known. "It can be perhaps be regarded as a population that is 'relict' in and ecological sense, though not in the geographical sense" Ricker 1960: 932).

Distribution

The Cultus Pygmy Sculpin appears to be endemic to the deep waters of Cultus Lake, in the Fraser River watershed (49°4'N, 122°0'W) of southwestern British Columbia (Figure 2).

Protection

No specific protection exists for this form, but general protection, if required, could be provided under British Columbia provincial wildlife and endangered species legislation.

Population Size and Trends

There is no information available on population size, and no evidence for determining trends in the

population. It appears that the species is common in Lake Cultus and reproducing successfully. Apparently first collected by Ricker in 1934 (Ricker 1960), specimens from collections in 1942 and 1951 have been preserved in the University of British Columbia Institute of Fisheries collection (BC 55-136, BC 54-433). Cannings (1993) "guestimated" a population size of 3000 to 10 000 fishes and indicated that no trend was discernible.

Habitat

This is a limnetic form restricted to the deeper waters of a low level montane lake. Direct evidence of spawning has not been observed, but breeding probably occurs in the deeper waters of the lake (Ricker 1960). The fish have not been observed in the shore waters and probably do not spawn there or in feeder or tributary streams since most of these are seasonal and dry up during the summer (Ricker 1960).

General Biology

Spawning has not been observed and the location of spawning is not known. Observation of females with large eggs indicates spawning begins in late May or early June and may continue through the summer (Ricker 1960) with the peak in July. The fate of newly hatched fry is not known. In the parent form, the larvae become planktonic and do not take up a benthic life until about 32 to 35 days post-hatch (Scott and Crossman 1973).

Ricker (1960) used approximations based on size group to develop a possible age structure for the population and concluded that the fish became sexually mature in the third year. No growth information is available, but maximum size is about 5.0 cm (Ricker 1960). Maximum age is not known, but the maximum age for the parent form is four years (Scott and Crossman 1973).



FIGURE 2. Canadian distribution of the Cultus Lake Pygmy Sculpin (*Cottus* sp.).

The diet consists of *Daphnia* sp., chironomid midge larvae and pupae, *Epischura* sp., ostracods, *Bosmina* sp., and *Cyclops* sp. One fish of 37 mm had consumed a smaller cottid of 14 mm in length (Ricker 1960).

Predator-prey relationships are not certain. The form is eaten by Dolly Varden, *Salvelinus malma*, which are also confined to the deeper waters of the lake. Ricker (1960) reported up to 100 of these sculpins in a Dolly Varden stomach. Cutthroat Trout, *Onchorhynchus clarki*, and Coho Salmon, *Onchorhynchus kisutch*, may utilize the larvae, but would rarely encounter adults as these species feed closer to the water surface (Ricker 1960). No Sculpins were found in Dolly Varden stomach contents from December to March (Ricker 1960), but this may reflect differences in Dolly Varden feeding behaviour than in sculpin activity. There is no indication that the Cultus Pygmy Sculpins utilize Dolly Varden or salmon eggs and fry as has been noted for the parent form (Scott and Crossman 1973).

The morphological adaptations (reduced bone density and increased subcutaneous lipids) are probably both adaptations to vertical migrations within the upper limnetic zone (Cannings 1993). No information on parasites in this form is available. Only two parasites have been reported for the parent form, the protozoans *Cryptobia lynchi* and *Cryptobia salmositica* (Hoffman 1967).

Limiting Factors

The population is reproducing successfully and is probably stable although no evidence for trends is available. The species is preyed upon by Dolly Varden and Cutthroat trout and any increase in trout populations could deplete or eliminate the population.

Ultimately, the major threat to the species is the transplantation of exotic species such as the Pumpkin Seed (*Lepomis gibbosus*) and the Catfish (*Ameiurus nebulosus*) which could extirpate populations of small fish in diminutive lakes in two years (McPhail 1989).

Special Significance of the Species

This form is of interest to man as it serves (or served) as a forage fish for salmonids and of considerable scientific interest as an example of neotonic evolution. The existence of a similar fish in a Washington Lake is also of interest as a possible case of independent parallel evolution.

Evaluation

The form is confined to the Cultus Lake and is a unique Canadian endemic. As a rare species, it is inherently at risk because of its restricted distribution.

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Status of the Spinynose Sculpin, *Asemichthys taylori*, in Canada*

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The Spinynose Sculpin, *Asemichthys taylori*, is a little-known marine sculpin found in Pacific coastal waters from the southern Strait of Georgia to southern Alaska. Information on the biology and ecology of the species is lacking and its geographic distribution is uncertain. It is apparently common where found, but there is too little information on which to base any decision on its status in Canada.

Le Chabot à Tête piquante, *Asemichthys taylori*, est un cottidé marin peu connu qui habite les eaux côtières du Pacifique à partir du sud du détroit de Géorgie à l'Alaska du sud. On manque de renseignements sur la biologie et l'écologie de cette espèce, et la répartition géographique est incertaine. Apparemment commun où il est trouvé, il y a peu d'information sur laquelle baser une décision sur leur statut au Canada.

Key Words: Spinynose Sculpin, Chabot à Tête piquant, *Asemichthys taylori*, British Columbia, endangered species.

Very little is known about the Spinynose Sculpin, *Asemichthys taylori* Gilbert, 1912 (Figure 1). Hart (1973) provides a physical description and distribution for the species as do Eschmeyer and Herald (1983), but no information on its biology and ecology. Lamb and Edgell (1986) provide some information on the habitat and comment on the overall lack of information on this fish. This report was undertaken to summarize the available information on the species for the Committee on the Status of Endangered Wildlife in Canada (COSEWIC).

Description

The Spinynose Sculpin is a small cottid seldom exceeding 5.7 cm in length (Hart 1973; Lamb and Edgell 1986), but may reach lengths of up to 7.6 cm

(Eschmeyer and Herald 1983). It is a typical cottid with a heavy head; elongated, slightly compressed body tapering evenly to the caudal peduncle; and large fan-like pectorals. There is a strong sharp nasal spine which curves back and three spines on the preopercular. The upper two are small and flat, the other very small. A row of tiny spinous projections is also found along the upper margin of each eye (Hart 1973).

The first dorsal fin has 10 or 11 spines, the second is higher with 15 or 16 rays; the caudal fin is slightly rounded; the anal fin is below the second dorsal and has 15 or 16 rays. The pelvic fins are thoracic and have one spine and three rays; the pectoral fins are large and fan like with 16 or 17 rays, the largest of which reaches to the third or fourth ray of

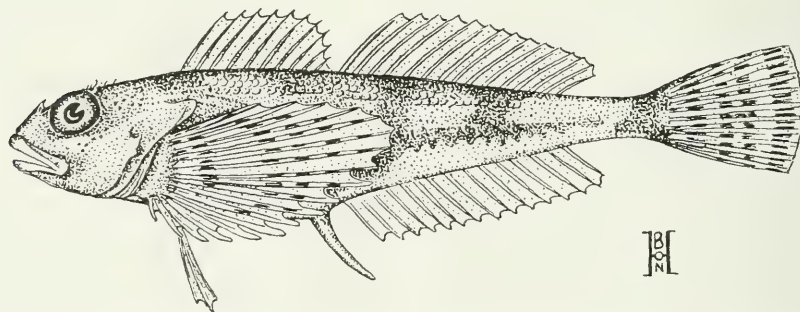


FIGURE 1. Spinynose Sculpin, *Asemichthys taylori*, 6.8 cm (drawing by D. R. Harriott from Hart 1973 by permission).

*Indeterminate status assigned by COSEWIC 16 April 1977.

the anal fin (Hart 1973). There are one to four rows of scales above the lateral line which extends from the head to the second dorsal fin or beyond. The lateral line slopes slightly downward from the anterior and then runs straight. It has 34 to 36 spinous, keeled plates forming a slight ridge (Hart 1973). The fish are olive-brown dorsally, and lighter laterally to almost white on the ventral surface, with four dark saddle-like blotches over the back and sides of the body. The pectoral and caudal fins have brown bars (Hart 1973).

Distribution

The distribution of the Spinynose Sculpin (Figure 2) is given as the coastal waters of the southern Strait of Georgia in Washington north to southern Alaska (Eschmeyer and Herald 1983). In Canada the species ranges from the Strait of Georgia to Tanu Harbour, Queen Charlotte Islands, northern British Columbia (Hart 1973; Lamb and Edgell 1986).

Protection

The species is given no specific protection in Canada or the United States (see Johnson 1987). General protection, if required, is not available under the Federal Fisheries Act of 1867, which applies only to commercial species, but could be provided under British Columbia provincial wildlife and endangered species legislation and regulations.

Population Sizes and Trends

There is no information on populations, other than presence and absence data. University of British Columbia collection records (UBC, no date) indicate that most Canadian collections have been made in Georgia Strait and the west coast of Vancouver Island. Records of collections made in 1934, 1962 and 1963 indicate that the species appears to be common where found, usually the third most plentiful species after other sculpins (example Longfin Sculpin, *Jordania zonope*) and gobies (*Cory-*



FIGURE 2. Canadian distribution of the Spinynose Sculpin, *Asemichthys taylori*.

phopterus nicholsi) [UBC, no date]. Apparently, there have been no specific attempts at collection of this species since 1963. There is no evidence on which to determine trends, although it was found in 1963 in the same general area where it was taken in 1934 (UBC, no date).

Habitat

Specimens collected in Canadian waters were found on substrates of sand and rock 30 to 61 cm in diameter in depths of 5 to 15 m within 30 to 60 m of shore. Water temperature was 9 to 12°C. (UBC, no date). Sparse vegetation consisting of *Laminaria* sp., corallines and *Sargassus* sp., were noted as was the presence of red and brown algae on the rocks (UBC, no date). Eschmeyer and Herald (1983) stated that the species is commonly found on shell bottoms near rocks at depths of 6 to 18 m. Lamb and Edgell (1986) reported that the Spinynose Sculpin rests on the bottom and may partially bury itself in shell hulls at the base of rocky outcroppings below 10 m. The species is difficult to see lurking among the red and brown algae or partially hidden in the shell hulls.

General Biology

No information available.

Limiting Factors

Not known.

Special Significance of the Species

The species is too small to be of interest as a food fish or bait fish for larger bottom fish (Lamb and

Edgell 1986). Because so much remains to be learned about the species, it should be of interest to science.

Evaluation

There is insufficient information on which to base any decision on the status of the species in Canada. The apparent Canadian distribution may be more a reflection of collection effort than the actual distribution of the species. It has not been collected in 34 years, but no specific efforts have been made to look for it.

Acknowledgments

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Status of the Chain Pickerel, *Esox niger*, in Canada*

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The Chain Pickerel, *Esox niger*, is a member of the pike family (Esocidae), and is similar to the Northern Pike (*Esox lucius*) but smaller. Canadian populations occur in southwestern Quebec, New Brunswick and Nova Scotia. The latter were introduced late in the 19th century, but it is not certain if the Quebec populations are native. These fish prefer acid waters, are voracious piscivores, and are usually solitary except during spawning. In some areas they are considered game fish, but in Canada few are taken by anglers. The species is not at risk in Canada.

Le Brochet maillé, *Esox niger*, est un membre de la famille des brochets ou Esocidae, il est semblable au Grand Brochet (*Esox lucius*) mais plus petit. Au Canada, on peut le trouver dans le sud-ouest du Québec, au Nouveau-Brunswick et en Nouvelle-Écosse, les populations du Nouveau-Brunswick et de la Nouvelle-Écosse furent introduites vers la fin du 19^e siècle. On ne sait pas si la population du Québec est indigène. Ces poissons préfèrent des eaux acidiques, sont des prédateurs voraces, et sont habituellement solitaires sauf pendant la frai. Dans certaines régions, particulièrement aux États-Unis, ils sont considérés une espèce sportive, mais au Canada peu sont attrapés par les pêcheurs. L'espèce n'est pas menacée au Canada.

Key Words: Chain Pickerel, Brochet maillé, *Esox niger*, endangered species.

The Chain Pickerel, *Esox niger* Lesueur 1818, (Figure 1) is a member of the pike family (Esocidae) and very similar to the Northern Pike (*Esox lucius*) in body shape and structure. Unfortunately, the term pickerel (= little pike) is used by many members of the public to refer to an unrelated fish, the percid, *Stizostedion vitreum*, the Walleye or Yellow Pickerel. The Chain Pickerel can be distinguished from other pikes (ie: Northern Pike, Redfin Pickerel, *Esox americanus americanus*; Grass Pickerel, *Esox americanus vermiculatus*; and Muskellunge, *Esox masquinongy*) by the network of lacey or chain-like markings on the sides which give rise to its common name.

Chain Pickerel are overall green to dark green dorsally, shading to green or blue-green on the sides, and cream or white below. The flanks are marked by yellowish green areas broken by the dark, interconnecting markings suggesting chain links. The cheeks and gill areas are scaled and there is a prominent, dark vertical line below the eye which may not be obvious in larger fish. Young fish are similar to the adult, but have a pronounced gold mid-dorsal stripe. The chain markings are not obvious in fish less than 15 to 20 cm in length (Scott and Crossman 1973).

Although similar in shape and appearance to the Northern Pike, Chain Pickerel have a smaller maximum size, averaging 38 to 46 cm in length and 0.5 to 1.0 kg in weight (Scott 1967; Scott and Crossman 1973). Maximum length appears to be about 76 cm and maximum weight not much more than 4 kg (Stroud 1955; Migdalski 1962; Scott and Crossman

1973). For a more detailed description of the species see Scott and Crossman (1973) and see Crossman (1962) for distinguishing characteristics of esocids. Crossman and Lewis (1973) have produced an annotated bibliography for the species.

Distribution

Chain Pickerel are primarily a freshwater fish of the Atlantic coastal plain on the east side of the Allegheny-Appalachian mountains. The range extends from Maine, south to central Florida, west through the Gulf States to the Nevasota River in Texas, and north in the Mississippi through eastern Arizona to southwestern Missouri and southwestern Kentucky and the Tennessee River system in Alabama (Figure 2). Its popularity as a game fish led to introductions west of the Allegheny-Appalachian mountains in Colorado, Nebraska, northern Kentucky, Minnesota, Indiana, Montanna, Ohio, and Pennsylvania, and the Lake Erie drainage of New York (Scott and Crossman 1973; Crossman 1980). Alterations to natural drainage for irrigation and land reclamation etc., have also led to various range extensions (see Crossman 1990).

In Canada, the species occurs in Nova Scotia, New Brunswick, and the Eastern Townships of Qubec (Figure 3) south of the St. Lawrence River (Scott and Crossman 1973). Possible native populations probably exist only in the Eastern Townships of Quebec as the species was clearly introduced into Nova Scotia (Scott and Crossman 1973; Crossman 1980, 1990) and New Brunswick (Cox 1896a).

In Nova Scotia, Chain Pickerel were introduced from the United States into Digby County (Scott and Crossman 1973; Crossman 1990). Scott and

*Species Not At Risk - COSEWIC 16 April 1997



FIGURE 1. Chain Pickerel, *Esox niger*, female 409 mm (drawing by A. Odum, from Scott and Crossman 1973 by permission of the authors).

Crossman (1973) state that the species exists only in Digby County, but Boates (J. S. Boates, Wildlife Resources, Nova Scotia Department of Natural Resources, Kemptonville, Nova Scotia; personal communication) indicates that the species is now more widespread there, although the full extent of the distribution is not known. It has turned up in the Tusketer River, Yarmouth County, and in such widely separated localities as Lily Lake, Hants County, Black River, Kings County, and Shorts Lake Colchester County (John Gilhen, Nova Scotia Museum, Halifax, personal communication; Gilhen 1974), and also

reported in Queens and Halifax counties (Bob Bancroft, Wildlife Resources, Nova Scotia Department of Natural Resources).

The species was introduced into New Brunswick (Cox 1896a,b) sometime in the 1800s. Cox (1896a) states that it was introduced into the St. John and St. Croix rivers, sometime after 1852 since the species had not been listed by Perly (1852). Scott and Crossman (1959) suggested that the first occurrence may have followed introductions into the St. Croix River in Maine about 1863. By 1970, Chain Pickerel were widely distributed in southern New Brunswick (Scott and Crossman 1959; Gorham 1970) being found in the lower St. John and St. Croix Rivers, and in the waters of Charlotte, Queens, Kings, Sunbury, and York counties, particularly in the St. John and Oromocto Rivers (New Brunswick Museum fish collection records, St. John, New Brunswick). Today it is more widespread and may be found almost anywhere suitable habitat exists (M. Sullivan, Fish and Wildlife Branch, New Brunswick Department of Natural Resources, Fredericton, New Brunswick; personal communication).

In Quebec, Chain Pickerel are found in the waterways of the Eastern Townships, north to the St. Lawrence River, Lac St. Pierre, the Richelieu and its tributaries, and the Yamaska River (Massé and Mongeau 1974; Mongeau et al. 1974; Mongeau 1979a,b). Although Scott and Crossman (1973) and others (Cuerrier et al. 1946; Legendre 1954; Roy et al. 1965; Bernatchez and Geroux 1991) gave the Canadian distribution of the species as the Eastern Townships of Quebec, Crossman (1990) suggested that the species may have been unintentionally introduced there. Crossman's (1990) inference may be based on the historic native distribution, which would seem to limit the species east of the Appalachians (Crossman 1980) and preclude it from Quebec. The completion of an inter-connection between the Hudson River and the Lake Champlain-Richelieu River system in 1819 may have created a route for range extensions north and west as is surmised for the Redfin Pickerel, *Esox americanus*



FIGURE 2. North American distribution of the Chain Pickerel, *Esox niger*.



FIGURE 3. Canadian distribution of the Chain Pickerel, *Esox niger*.

americanus (Scott and Crossman 1973). On the other hand, Cuerrier et al. (1946) included *Esox niger* as native to Quebec, and stated that it was common in the Eastern Townships, but rare in the St. Lawrence, where it was first recorded in 1941 (Cuerrier et al. 1946), whereas *Esox americanus vermiculatus* was first found in the province in 1941 (Cuerrier 1945; Cuerrier et al. 1946). Scott and Crossman (1973) presumed that the recent appearance of the latter was related to the range extensions through the man-made connections of the Hudson-Champlain-Richelieu systems rather than to post-glacial dispersal through the Lake Champlain-Hudson River discharge of the Great Lakes plain. Crossman (1980) attributed its presence in Vermont and Quebec to range extensions resulting from man-made waterways. However, Huot (M. Huot, Wildlife and Habitats Branch, Quebec Ministry of the Environment and Wildlife, Quebec, Quebec; personal communication) feels that the species is native and its Quebec distribution reflects its post-glacial distribution.

Even if the Chain Pickerel was not originally native to Quebec, it should now be considered as a "naturalized" member of the local fauna as it has probably been present in Quebec waterways for at least well over 50 years (Cuerrier et al. 1946) and perhaps since soon after the 1819 inter-connection of the Hudson-Champlain-Richelieu systems (see Monpetit 1987).

Protection

The species is widespread throughout its United States range and common where found, except for Kentucky where it is of special concern (Johnson 1987).

In Canada, the species has not been given any special recognition, and since it is not a "commercial" species, general protection is not available under the Habitat Sections of the Federal Fisheries Act.

Provincial legislation does not specifically mention the species under sport fishing regulations, but it is included with other esocids under the "pikes". In most areas the fishing season for pikes is closed during spawning and possession and bag limits are in place [e.g., six in Quebec (QEF 1995)]. The species may not be used as a bait fish or fished commercially; however, fish taken by sport fishing may be sold.

In Quebec, much of the habitat is in protected areas or areas being considered for protection (Hone 1988). Similar protection is not available in New Brunswick or Nova Scotia; in fact in Nova Scotia, some streams have been poisoned to stop the spread of the species (Ducharme 1964). Quebec and New Brunswick do have endangered species legislation which could provide protection status if required.

Population Sizes And Trends

There is very little information available regarding the abundance of this species in Canada. Most information is simply presence or absence data resulting

from captures by anglers and is often from the capture of a single specimen. In Nova Scotia, efforts have been made to prohibit the spread of the species (e.g., Ducharme 1964), but it may no longer be confined to waters in Digby County (Boates, personal communication) as stated by Scott and Crossman (1973). Although the extent of expansion is not certain the species is common where found.

In New Brunswick, it was widely distributed in the southern counties (Gorham 1970) and collections of one to six specimens have been made at various locations in Kings, Sunbury, Queens, Charlotte and York counties with seine and dip nets (New Brunswick Museum Collection Records, St. John, New Brunswick). The Chain Pickerel now enjoys a wider distribution in the province where it is considered common, and a threat to other game fishes (Sullivan, personal communication).

Likewise, there is very little information about the abundance of the species in Quebec. Cuerrier et al. (1946) stated that the species was common in the Eastern Townships, but rare in the St. Lawrence River. Mongeau (1979a) found the species to be present in 5 to 10 % of sites surveyed in the Yamaska Basin where suitable habitat existed. Similar frequencies were found in the Richelieu River and in regions of Lake St. Pierre (Massé and Mongeau 1974; Mongeau et al. 1974; Mongeau 1979b). Huot (personal communication) indicates that the Quebec populations appear to be stable and that the species is not in jeopardy.

Records for the species in Canadian waters of Ontario, Toronto Harbour, and Kingston are based on young fish described by Nash (1908), which were probably juvenile Northern Pike which bear a superficial resemblance to young of the Chain Pickerel (Scott and Crossman 1973).

Since the species is found in the upper St. Lawrence River as far west as Montreal and Chateaugay (Mongeau et al. 1974), it would seem possible for an upstream extension into Lake Ontario. Perhaps polluted habitat around Montréal has prevented further upstream expansion as suggested for the Redfin Pickerel by Scott and Crossman (1973). Mongeau et al. (1982) indicated that virtually all fishes were annihilated from the waters around Montréal, especially the Lake of Two Mountains during the 1950s, by pollution and waste disposal, primarily from the pulp and paper industry (Le Sautes 1967; Mongeau and Massé 1976). Restoration since 1964 has resulted in an increase in most species and some have returned to normal abundance. This might have presented a barrier during the middle decades of this century, but should not now be the case.

Odell (1932, 1933, 1938) found that the Chain Pickerel was not abundant in New York streams, but this is to be expected of solitary, highly predacious species.

Habitat

The Chain Pickerel is usually found in sluggish streams and shallow (water depth of 3 m or less) lakes and ponds with heavy vegetation, the same habitat preferred by most esocids. Scott and Crossman (1973) give summer surface temperatures of such habitat as 20 to 30°C, but Chain Pickerel may be able to tolerate temperatures of up to 37°C. They have also been found in deeper lakes and larger streams with cooler temperatures (Crossman 1980). Chain Pickerel can tolerate brackish waters with salinities as high as 15‰ (Scott and Crossman 1973; Crossman 1980), but prefer slightly acid water and have been found in waters with a pH of 3.8 (Buck and Thoits 1970).

Larger fish move into shallow water and shoals during the day and retire to deeper water at night, and may migrate to brackish areas in winter (Scott and Crossman 1973). Armbruster (1959) found that in Ohio, Chain Pickerel prefer deeper, cooler waters during mid-summer and move into shallow weedy areas in the fall when the water is cooler. In spring, fish move into marshy, shallow water for spawning shortly after the ice leaves. Spawning is said to occur in shallow (1 to 3 m) water over flooded vegetation at temperatures of 2 to 22°C in April and May (Armbruster 1959; Scott and Crossman 1973), although they may spawn earlier if the ice is gone and water temperature is above 0°C (Emboly 1918). Eggs are slightly adhesive and stick to vegetation and fry remain in shallow water and attach themselves to vegetation by the adhesive gland on the lip of the snout (Scott and Crossman 1973).

General Biology

Since it is not of commercial importance, and of little importance as a sport fish, there is little published information on Canadian populations of the species. Wick and Mullen (1958), McCabe (1958) and Carlander (1969) have summarized data on populations in the United States, and Scott and Crossman (1973) have drawn together information on U.S. populations where environmental conditions approximate those in Canada and the following is based on their summaries. A detailed list of citations including other sources of information on the biology of the species, may be found in Crossman and Lewis (1973).

Like other esocids, the Chain Pickerel is primarily a spring spawner, although fall spawning has been observed (Miller 1962). Spawning occurs in the spring as soon as the ice melts at water temperatures of 2 to 22°C (Emboly 1918; Armbruster 1959). Spawning takes place in shallow water (1 to 3 m) in marshy areas or flooded benches of streams, lakes and/or ponds over submerged vegetation. Spawning may extend over a period of 7 to 10 days, no nests are built and the eggs are shed over the substrate.

Duplinsky (1982) found that sperm motility in Chain Pickerel is acid tolerant with maximum motility at a pH of 6.9, but sperm swimming activity may last up to 90 seconds at a pH as low as 3.9. Sperm motility decreased at basic levels (pH >7.4). On the other hand, opposite results were noted for Northern Pike, thus acidity could be a chance reproductive barrier, reducing the risk of hybridization where the species exist in the same waters. There must be an overlap between species. If there is, then a barrier might exist at pH extremes.

The eggs are about 2 mm in diameter, yellow, demersal and slightly adhesive. Females of 31 to 36 cm in length (Rhode Island) may contain 6000 to 8000 ripe eggs, larger fish may have more eggs. The eggs hatch in 6 to 12 days depending on water temperature. The fry are 4.2 to 7.0 mm in length, have poorly formed mouths, and have an adhesive gland on the tip of the nose by which they attach themselves to the substrate or surface scum. They exist on the yolk sac for about one week, over which time the mouth develops and they reach approximately 10 mm in length. Swim-up fish feed on zooplankton for a week or more, then on invertebrates, immature aquatic insects and small fish. At a length of 1.0 to 1.5 cm they begin to feed almost exclusively on fish. Mansueti and Hardy (1967) have outlined egg, larvae and juvenile development and provide a taxonomic description of adults and notes on ecology and spawning.

Growth is variable depending on food availability, water condition, fish community associations and population density (*see* Underhill 1949). In small ponds or under crowded conditions, growth is limited (Scott and Crossman 1973). There is a sexual disparity in growth rates, females grow faster, mature earlier, attain a larger size and live longer than males. Chain Pickerel live an average of 3 to 4 years, but may attain an age of 8 to 9 years under certain conditions. Growth may be faster in the south and maturity may be reached as early as 1 year whereas growth is slower in the north where it may take 3 to 4 years to reach sexual maturity (*see* Underhill 1949; McCabe 1942, 1958; Mansueti and Hardy 1967; Carlander 1969).

The average size of the adult is 38 to 46 cm with an average weight of 0.4 to 0.7 kg, maximum length is about 76 cm with a maximum weight of 2.7 kg (Scott and Crossman 1973).

Behaviour

Chain Pickerel are predacious carnivores and they are solitary fish, spending most of their time hiding motionless in patches of vegetation. They move into shallow waters at night to feed and back into deeper water during the day (McCabe 1958). They may establish a defined territory during the summer and leave it only to feed. They usually move into deeper brackish water in winter and can tolerate salinity of up to 15‰, and acidic waters to pH 3.8, but are sen-

sitive to higher pH (Buck and Thoits 1970). Feeding continues in the winter under the ice (Scott and Crossman 1973).

Spawning Behaviour

Adults move into the spawning areas, flooded benches of lakes streams or ponds, soon after the ice is out. Spawning usually takes place during the day. No nests are built. Single females swim randomly over the submerged vegetation, closely accompanied by one or two males. From time to time the female and a male roll inward and flex their bodies to bring the vents into proximity. The eggs and sperm are shed at the same time and the eggs are dispersed over the substrate by shaking of the caudal fins. A single female may spawn several times over the course of one or two days until all the eggs are shed. There is no parental care of the eggs (McCabe 1958; Scott and Crossman 1973).

Diet

Newly hatched fish are planktivorous for a week or more, quickly shifting their diet to invertebrates (mostly aquatic insects) and small fish. Fish become more important in the diet as the young fish grow. By the time they reach the size of 10 to 15 cm, other fish are the principal source of food, although frogs and crayfish are taken as well (McCabe 1958; Flemer 1959; Scott and Crossman 1973). The Chain Pickerel is not particularly selective in its choice of prey, with over 37 species of prey recorded, including minnows, sunfishes, catfishes, and other pikes (Scott and Crossman 1973; Peterson and Martin-Robichaud 1982); trout and salmon (Keith and Barkley 1971; Warner 1972), basses (Cott 1934), and perches (Raney 1942; Doxtater 1967) have also been noted and the species is cannibalistic under certain conditions (Anonymous 1968). Although they appear to have a preference for spiny-rayed fishes (McIlwin 1970), this may be an artifact of prey availability. Chain Pickerel are opportunistic predators, taking whatever is available while it is alive and small enough to be eaten (snakes, mice, frogs). Studies have indicated that the species can swallow prey where the body depth is less than or equal to its own (Lawrence 1960).

Parasites

Thirty-six parasites have been listed as parasitic on Chain Pickerel. These include Protozoans, Trematodes, Cestodes, Nematodes and Acanthocephalans, leeches and one species of crustacean (*see* Hoffman 1967).

Predator/Prey Relationships

Adult Chain Pickerel are predacious piscivores with a voracious appetite, however the number of predators (on Chain Pickerel) is probably dependant on the habitat. Those in acid water and shallow water habitats have few competitors (Scott and Crossman 1973). Young fish (less than 15 cm in length) may

be preyed upon by a variety of other fishes including basses, sunfishes, perches and other pickerels (De Jean 1951; Buck and Thoits 1967; Duxtater 1967; Scott and Crossman 1973). Birds (herons, loons, mergansers, grebes and kingfishers) frogs, otters, and man are also predators. Young fish must compete with all other fish in the habitat which depend on invertebrates (Scott and Crossman 1973).

Limiting Factors

In some areas the Chain Pickerel is considered a game species (e.g., Greeley 1927; Anonymous 1962a,b; Musick 1962). In Canada it is not usually thought of as a sport fish, and may be released if caught by anglers. In Québec and New Brunswick, some may be sold fresh from the fyke and hoopnet fisheries (Scott and Crossman 1973). Predation by other piscivores, birds, frogs, etc., particularly of smaller individuals, may be limiting in areas where large concentrations of other predators abound. DeJean (1951) and Duxtater (1967) have shown that in some ponds the presence of species such as Bluegill (*Lepomis macrochirus*) and Warmouth (*Lepomis gulosus*) may result in high mortality due to predation.

Choice of spawning areas could also be limiting as the species tends to use the flood benches of streams, lakes and ponds. Eggs and/or young may be stranded when water levels recede. Water quality may also be important, as Chain Pickerel are sensitive to high pH (Buck and Thoits 1970; Duplinsky 1980). Pollution may also be limiting range extensions (*see* Population Sizes and Trends above).

Introgressive hybridization may also be a factor. Chain Pickerel readily hybridize with the Redfin Pickerel to produce fertile offspring (Scott and Crossman 1973), while crosses with Northern Pike are not fertile. The Redfin Pickerel may be sympatric with the Chain Pickerel in some parts of the Quebec range, but the Redfin Pickerel is not abundant (Coffie 1996). Non-fertile hybrids of the pike cross are known from Québec and New York (Crossman and Buss 1965), and Raney (1955) mentioned natural hybrids of *Esox lucius* × *Esox niger* in Massachusetts.

Special Significance of the Species

In some states of the U.S. along the eastern seaboard, the species is highly regarded as a sport fish and large numbers are taken annually (e.g., Musick 1962). They are stocked in ponds and production may be as high as 66 kg/ha where the ponds are barren of predators (Scott and Crossman 1973). In Canada, it is not considered as a sport fish, but some are taken in net fisheries in the Maritimes and Quebec and sold commercially (Scott and Crossman 1973). In some areas they have been introduced to control unwanted or nuisance species (Buntz 1967; Duxtater 1967; Scott and Crossman 1973).

Evaluation

Chain Pickerel were introduced into New Brunswick and Nova Scotia. It is not certain whether this species is native to Québec or the result of incidental introduction as a range extension via man-made diversions to natural waterways (Hudson-Champlain-Richelieu systems). It has been present in Québec, New Brunswick and Nova Scotia for well over 50 years and should be considered a "naturalized" species (particularly in Québec). In any event, the species does not appear to be at risk in Canada, populations are stable or even expanding (in Nova Scotia) in suitable habitats and there is no evidence of a decline.

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Status of the Eastern Silvery Minnow, *Hybognathus regius*, in Canada*†

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The Eastern Silvery Minnow, *Hybognathus regius*, is a member of the family Cyprinidae. It is widely distributed along the Atlantic Slope from Québec south to Georgia. In Canada, it is restricted to the eastern Lake Ontario, Ottawa River and St. Lawrence River drainages of eastern Ontario and Québec. No specific legal protection for this species exists in Canada or the United States. This species seems to be less sensitive to turbidity and siltation than other species in the genus *Hybognathus*, and populations appear to be stable over much of its range in Canada.

Le Méné d'argent, *Hybognathus regius*, est une membre de la famille Cyprinidae. On le trouve sur tout le versant Atlantique du sud du Québec à la Georgie. Au Canada, il est limité aux bassins de l'est du Lac Ontario, de la rivière Ottawa et du fleuve Saint-Laurent dans l'est de l'Ontario et du Québec. Au Canada et aux Etats-Unis il n'y a aucune législation spécifique pour cette espèce qui semble moins sensible à la turbidité et à l'envasement que les autres espèces dans le genre *Hybognathus*. Les populations paraissent stables sur la plus grande partie de sa répartition canadienne.

Key Words: Eastern Silvery Minnow, Méné d'argent, *Hybognathus regius*, Cyprinidae, Ontario, Québec.

The Eastern Silvery Minnow, *Hybognathus regius* (Girard, 1857), [Figure 1] is one of seven species of the genus *Hybognathus* in the family Cyprinidae (Robins et al. 1991; Schmidt 1994). Species in the genus *Hybognathus* are characterized by elongate intestines coiled on the right side, black peritoneum, and subterminal mouths with crescent-shaped lower jaws (Scott and Crossman 1973; Page and Burr 1991), and origin of dorsal fin anterior to origin of pelvic fins (McAllister and Coad 1974). Schmidt (1994) identified three additional morphological characters that support the monophyly of *Hybognathus*: elongate anterior processes of the urohyal; enlarged epibranchials; and, organization of pharyngeal papillae. Three species of *Hybognathus* are present in Canada. *Hybognathus regius* [= *H. nuchalis* in Scott and Crossman (1973) and McAllister and Coad (1974)] can be distinguished from the sympatric *Hybognathus hankinsoni* by a pointed dorsal fin and silvery colour (Scott and Crossman 1973), the possession of four scales between the lateral line and the pelvic fins, a thin black line along side of the body partly over the dark lateral band, and 5 to 12 radiating grooves on scales lateroventral to dorsal fin (McAllister and Coad 1974). The third Canadian species, *Hybognathus argyritis*, is found only in extreme southern Alberta and Manitoba. The average size of the Eastern

Silvery Minnow is approximately 76 mm total length (TL) with a maximum length of 120 mm TL (Scott and Crossman 1973).

Hubbs and Lagler (1947) believed *Hybognathus nuchalis* and *Hybognathus regius* were subspecies with intergrades present in the gulf states. Although Bailey (1954) concluded no zone of intergradation existed and the allopatry of *Hybognathus regius* and *Hybognathus nuchalis* precluded gene exchange, he recommended the subspecific rank be maintained. Pflieger (1971) recommended *Hybognathus nuchalis* and *Hybognathus regius* be considered distinct species based on the differences in the shape of the basioccipital process. The Eastern Silvery Minnow can be distinguished from the allopatric *Hybognathus nuchalis*, found primarily in lowland areas of the Mississippi River basin by possession of a narrower, straight-edged, basioccipital process (Page and Burr 1991). A recent study of the pharyngeal papillae that form a pharyngeal filtering apparatus in *Hybognathus* concluded that "*Hybognathus argyritis*, *Hybognathus regius*, and *Hybognathus amarus* are specifically distinct from *Hybognathus nuchalis*" (Hlohowskyj et al. 1989: 181). Based on 12 osteological characters and pharyngeal papillae (from Hlohowskyj et al. 1989), Schmidt (1994) concluded that *Hybognathus regius* formed an unresolved trichotomy with *Hybognathus hankinsoni* and a monophyletic *Hybognathus nuchalis* species group containing the remaining five species of *Hybognathus*. *Hybognathus hankinsoni* and *Hybognathus regius* were distinguished from the *Hybognathus nuchalis* species group on the basis of absence of derived characters.

*Species Not At Risk - COSEWIC 16 April 1997.

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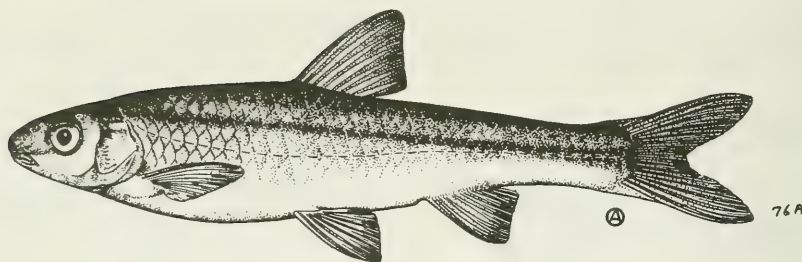


FIGURE 1. Eastern Silvery Minnow, *Hybognathus regius*.

Distribution

The Eastern Silvery Minnow is found along the Atlantic Slope of the Appalachian Mountains from the St. Lawrence River in Québec, south to the Altamaha River drainage in Georgia (Lee 1980; Figure 2, inset). In the northern part of its distribution, it is found from the Lake Champlain and Finger Lakes drainages, the St. Lawrence River drainage, west to the eastern Lake Ontario drainage, and north in the Ottawa River drainage to Graham Bay, just upstream of the city of Ottawa.

In Ontario, *Hybognathus regius* was collected before, but not after, 1970 in a Gananoque River tributary, the St. Lawrence River at Brown's Bay, three sites on the Ottawa River from Graham Bay downstream to the Pointe Fortune dam, and in eight Ottawa River tributaries. Specimens have been collected since 1970 in two Lake Ontario tributaries in Prince Edward County, three sites on the St. Lawrence River, the Ottawa River at Upper Duck and Kettle islands, one site on the Ottawa River downstream of the city of Ottawa, and one Ottawa River tributary. The species was collected both before and after 1970 in two Ottawa River tributaries (Figure 2). Appendices containing detailed collection records are on file with the COSEWIC Secretariat and are available on request.

The distribution of the Eastern Silvery Minnow in Québec has been well documented in publications of the Service de L'Amenagement de la Faune, Ministère du Loisir de la Chasse et de la Pêche (MLCP), Québec (Massé and Mongeau 1974, 1976; Mailhot et al. 1981; Mongeau et al. 1974; Mongeau 1979, 1985) and the Ministère de l'Environnement et de la Faune (Richard 1994) and LaViolette (1996). It was collected before, but not after, 1970 at three sites on the Ottawa River just upstream of the Pointe Fortune Dam, and in one of its tributaries near Hull; Lac MacDonald; Lac Gemont; Lac des Deux Montagnes and two of its tributaries; three sites on the St. Lawrence River near Montréal and one tributary upstream of Montréal; Baie Missisquoi of Lake Champlain and four of its tribu-

taries; and, in three Lac Memphrémagog tributaries. It has been collected in Québec since 1970 at one site on the Ottawa River just downstream of Hull, and in one of its tributaries; at 263 sites on the St. Lawrence River, and in 18 of its tributaries; Lac Brome; and, in one tributary of Lac Memphrémagog. It was collected both before and after 1970 in Lac des Deux Montagnes, and one of its tributaries; Lac St. Pierre; four St. Lawrence River tributaries; and, Lac Memphrémagog (Figure 2).

Several questionable records have been excluded from this report. The collections of *Hybognathus nuchalis* reported by Meek and Clark (1902) from "Hawkestone" (Hawkestone) on Lake Simcoe (Field Museum of Natural History (FMNH) 3077), and Bala on Lake Muskoka (FMNH3118) were reidentified as *Hybognathus hankinsoni* [E. Holm, Royal Ontario Museum (ROM), Toronto, Ontario, personal communication]. The Hawkestone record has also been erroneously cited by Rawson (1930) as "Meek 1902", and by MacCrimmon and Skobe (1970) who reported the location as Atherley, not Hawkestone. Fowler (1918) was unable to find the specimens needed to verify the record of *Hybognathus nuchalis* in the Detroit River near Grosse Isle (Cope 1864). Three dots representing records of *Hybognathus regius* along the north shore of Lake Ontario are found on the map for *Hybognathus nuchalis* in Lee (1980). Neither collection data nor voucher specimens have been found to verify the presence of this species at these localities. Richard (1994) reported the collection in 1990 of the Eastern Silvery Minnow at three adjacent sites in the Rivière L'Assomption watershed of Québec. No voucher specimens are available for these sites; therefore these records were excluded from this report.

Protection

No specific legal protection exists for *Hybognathus regius* in Canada or the United States. The Eastern Silvery Minnow is listed as being of "Special Concern" in Massachusetts (Johnson

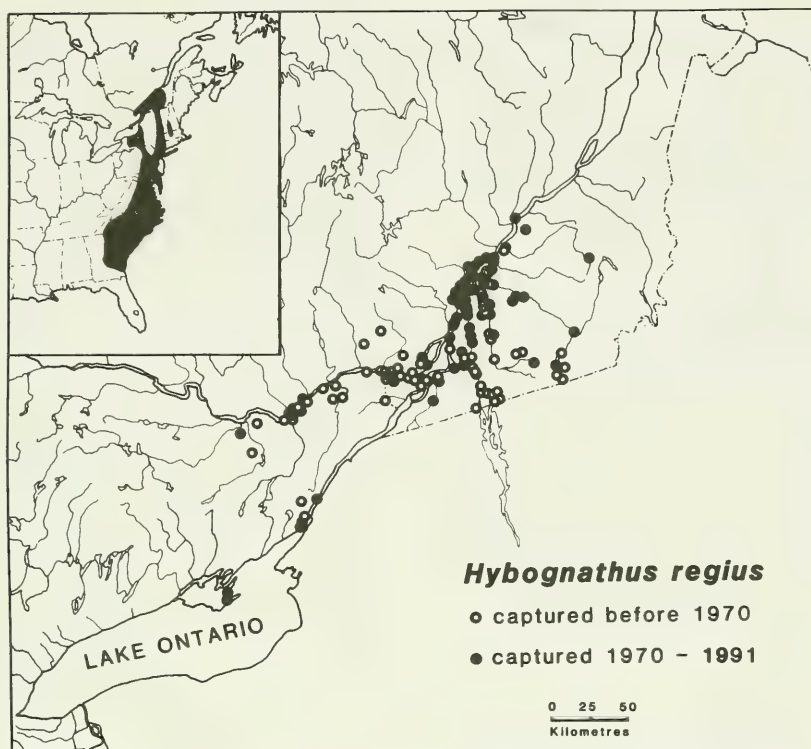


FIGURE 2. Canadian distribution of the Eastern Silvery Minnow. Inset map: North American distribution (modified from Lee 1980).

1987). Four other species of *Hybognathus* are of "Special Concern" in several states peripheral to their principal distribution. However, these species are not listed in most of the states or provinces within their principal distribution. *Hybognathus nuchalis* is protected in New Mexico and *Hybognathus placitus* is protected in Tennessee (Johnson 1987). The status of the Western Silvery Minnow, *Hybognathus argyritis*, in Canada has been designated as vulnerable in April 1997 (see Houston 1998).

The species and/or its habitat may also be protected by the Canada Environmental Assessment Act, Canada Environmental Protection Act, Canada Fisheries Act, Canada Shipping Act, Canada Water Act, Canada Wildlife Act, Ontario Environmental protection Act, Ontario Environmental Assessment Act, Ontario Game and Fish Act, Ontario Planning Act and Ontario Water Resources Act. Québec also has endangered species, wildlife and environmental legislation which could be used to provide protection of required.

Population Size and Trends

Although no specific studies on the population size or trends of the Eastern Silvery Minnow have

been carried out, some inferences can be made from the available information. In Québec, the species has been recorded in 492 collections. Prior to 1960, the species was captured at 15 sites; and, between 1960 and 1969, the species was captured at 130 sites. Between 1970 and 1979, the species was captured at 318 sites including the collection of 12 267 specimens in the channels of Iles de Sorel and Iles de Berthier and 11 296 specimens in Lac St-Pierre (Massé and Mongeau 1974). Since 1980, the species was captured at nine sites including the easternmost record in the St. Lawrence drainage.

In Ontario, the species has been collected at 35 sites. Ten of the 11 collections made before 1960 were made in the late 1930s by G. C. Toner (ROM, unpublished data). Toner noted that "the bait seiners catch considerable numbers in the Ottawa River" (Toner 1943: 48). Between 1960 and 1969, *Hybognathus regius* was collected at six new sites, and three sites where it had been collected prior to 1960. Between 1970 and 1979, the species was captured at 13 sites. Since 1980, it was captured at five new sites, and at one site where it was previously captured in 1970. Among the five new sites were the northernmost record in the Ottawa River, and the westernmost record in Lake Ontario.

Therefore, collection data for the Eastern Silvery Minnow indicate populations are stable or expanding over much of its distribution in Canada. It cannot be determined if the lack of collection data since 1970 in the Ottawa River, Lac des Deux Montagnes, and Baie Missisquoi of Lake Champlain is the result of decline in sampling effort or in population numbers.

Habitat

The preferred habitat of *Hybognathus regius* is the shallow inshore areas of large lakes and rivers (Scott and Crossman 1973). In Ontario, the Eastern Silvery Minnow has been primarily found over substrates of sand and mud, or of sand and gravel, in slow-moving or still water (ROM, unpublished data). Nakashima et al. (1977) found the abundance of the species in the littoral zone of Lac Memphrémagog, Québec was higher in the eutrophic south basin than in the oligotrophic north basin. They hypothesized this was the result of increased availability of detrital food resources in the south basin.

General Biology

Reproductive Capacity

Much of the information that is known about the reproductive biology of *Hybognathus regius* resulted from observations of populations in Cayuga Lake, New York (Raney 1939). Spawning took place in heavily vegetated backwaters and 2000 to 6600 nonadhesive eggs were laid over bottom ooze. The eggs hatched in six to seven days with the water temperature varying between 13.3°C and 20.5°C. When propagated in ponds, the Eastern Silvery Minnow reached maturity and spawned at age two, and spawned again the following year (Raney 1942). In Canadian waters, it is believed that the species spawns in May, although no observations have been published (Scott and Crossman 1973).

Species Movement

Hybognathus regius has been observed to migrate to spawning grounds in large schools. In southern New York state, Raney (1939) noted that this migration reached its peak in April 1938. In Lac Memphrémagog, Québec, large postspawning congregations of the Eastern Silvery Minnow occurred in one bay in early summer, May to July 1974 and 1975 (Gascon and Leggett 1977).

Behaviour/Adaptability

The diet of *Hybognathus regius* has been described as consisting of diatoms, algae, and bottom ooze (Raney 1939). Hlohowskyj et al. (1989) stated the pharyngeal papillae found in all *Hybognathus* species may be an accessory filtering

system to the gill arches adapted for herbivory. Gascon and Leggett (1977) described changes in the diet of the Eastern Silvery Minnow in Lac Memphrémagog. The diet of 0+ fish changed from cladocerans (82% by volume), rotifers (8.4%) and chironomids (7%) to organic detritus (95%) and cladocerans (3%), as the average fork length (FL) increased from 32 mm to 44 mm. Individuals greater than 40 mm FL fed almost exclusively on organic detritus, except in June when 46% of their diet was cladocerans.

Limiting Factors

McAllister and Coad (1974) noted that *Hybognathus nuchalis* is sensitive to turbidity and siltation which are cited as likely causes of population declines of *Hybognathus nuchalis* in Missouri and Ohio (Pflieger 1975; Trautman 1957). Hlohowskyj et al. (1989) hypothesized the finer, densely crowded pharyngeal papillae of *Hybognathus nuchalis* may be a factor in this sensitivity. Two other species of *Hybognathus*, *Hybognathus amarus* and *H. placitus*, are found in turbid habitats. These species have shorter, less crowded papillae and appear to be well-adapted to silty environments (Hlohowskyj et al. 1989). *Hybognathus regius* possess pharyngeal papillae intermediate to those in the above species (Hlohowskyj et al. 1989), and may be less sensitive to turbidity and siltation than *Hybognathus nuchalis*. A decrease in abundance of *Hybognathus regius* and other fish species in areas exposed to ship-induced wave action has been documented in the St Lawrence River at Montréal (Massé and Mongeau 1976).

Special Significance of the Species

The Eastern Silvery Minnow is an economically important and frequently used baitfish in ice fishing for yellow perch in the Montreal region (P. Dumont and G. Roy, MCLP-Montréal, personal communication). Although it has been used as a baitfish in Ontario (Toner 1943), the extent of its current use in Ontario is unknown.

Evaluation

The Eastern Silvery Minnow is present throughout most of its historical distribution in Canada. The recent collection of specimens in Ontario, and the abundance of specimens recently collected at numerous sites in Québec suggests that populations of this species are stable in Canada.

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Status of the Western Silvery Minnow, *Hybognathus argyritis*, in Canada*

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The Western Silvery Minnow (*Hybognathus argyritis*) is known in Canada only from Alberta, where it was first collected in 1961. It is no doubt native to the Alberta fauna and may have been previously overlooked or misidentified as the Brassy Minnow (*Hybognathus hankinsoni*). Intolerant of siltation and habitat degradation, this species should be considered vulnerable in Canada given its restricted distribution and rarity.

Le Méné d'argent de l'ouest (*Hybognathus argyritis*) est connu au Canada seulement de l'Alberta d'où il fut collectionné en 1961. C'est sans doute une espèce native de la faune de l'Alberta, qui aurait au paravant échappé aux regards, ou qui aurait peut-être été mal identifiée avec le Méné laiton (*Hybognathus hankinsoni*). Cette espèce ne supporte pas l'envasement et la dégradation de habitat, et doit être considéré comme une espèce vulnérable au Canada à cause de sa répartition limitée et sa rareté.

Key Words: Western Silvery Minnow, Méné d'argent de l'ouest, *Hybognathus argyritis*, rare fishes, endangered species, Alberta.

The Western Silvery Minnow, *Hybognathus argyritis* Girard, 1856, is a small cyprinid (average length 7.6 cm) of the American mid-west in the Missouri River basin. In Canada, the species is known only from the Milk River and South Saskatchewan River systems in Alberta (Scott and Crossman 1973; Nelson and Paetz 1970, 1992), although Scott and Crossman (1973) give its Canadian range as including southern Manitoba based on one collection from a tributary of the Souris River. However, this citation is in error as the Manitoba specimens, which were catalogued in the Royal Ontario Museum (ROM) collection, were actually verified by E. Holm (ROM) in 1982 as the Brassy Minnow, *Hybognathus hankinsoni*, a sympatric species (K. W. Stewart, Department of Zoology, University of Manitoba, Winnipeg, Manitoba; personal communication).

This synopsis is a result of a request from officials of Alberta Natural Resources to have the species considered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC), for possible status determination.

Systematic Note

The genus *Hybognathus* contains seven species in North America, three of which are found in Canada; i.e., the Western Silvery Minnow, the Eastern Silvery Minnow, *Hybognathus regius*, and the Brassy Minnow (Robins et al. 1991; Schmidt 1994).

Live specimens of *Hybognathus argyritis* can be distinguished from the sympatric Brassy Minnow by a pointed dorsal fin and silvery colour (Scott and Crossman 1973; Nelson and Paetz 1992), the possession of four scales between the lateral line and the pelvic fins, a thin black line along side of the body partly over the dark lateral band, and five to 12 radiating grooves on scales lateroventral to the dorsal fin (McAllister and Coad 1974). *Hybognathus regius* is confined to the Atlantic drainage and is found in Canada only in southwestern Quebec and southeastern Ontario (see Scott and Crossman 1973; Lee 1980 and status report in this issue). *Hybognathus nuchalis*, the Mississippi, or Central (Pflieger 1980a), Silvery Minnow occurs in the Mississippi basin and adjacent Gulf slope.

Fishes of this genus are characterized by elongate intestines coiled on the right side, a black peritoneum, and subterminal mouths with crescent-shaped lower jaws, (Scott and Crossman 1973; Page and Burr 1991), and origin of dorsal fin anterior to origin of pelvic fins (McAllister and Coad 1974). Three additional morphological characters that support the monophyly of the genus are the longate anterior processes of the urohyal; enlarged epibranchials; and, organization of pharyngeal papillae (Schmidt 1994).

Along with *Hybognathus regius*, the Western Silvery Minnow was formerly treated as a synonym of *Hybognathus nuchalis*, the Central Silvery Minnow (Pflieger 1980a,b). Scott and Crossman (1973) treated them as subspecies, namely *Hybognathus nuchalis nuchalis* in the west and *Hybognathus nuchalis regius* in the east. Pflieger (1971) recommended that *Hybognathus nuchalis*,

*Vulnerable status assigned by COSEWIC 16 April 1997.

Hybognathus argyritis and *Hybognathus regius* be considered distinct species based on the differences in the shape of the basioccipital process and this has been accepted by the American Fisheries Society (Robins et al. 1991). However, Nelson and Paetz (1992) noted a wide range of variation in Milk River specimens and concluded that a more detailed study of the character and its relation to the significance of *Hybognathus* taxonomy is needed. Other recent systematic studies of the genus (Hlohowskyj et al. 1989; Schmidt 1994) concluded that *Hybognathus argyritis* was morphologically similar to *Hybognathus regius*, but could be also distinguished from *Hybognathus regius* and *Hybognathus nuchalis* by differences in the pharyngeal papillae that form a pharyngeal filtering apparatus in *Hybognathus*.

Description

The average size of the Western Silvery Minnow (Figure 1) is approximately 76 mm total length (T.L.) with a maximum length of 125 mm T.L. (Pflieger 1980b; Scott and Crossman 1973). Maximum length in Alberta is 10 cm fork length (Nelson and Paetz 1992). The body is elongate, moderately compressed laterally and has a stout caudal peduncle. The head is short, bluntly triangular with a moderately large eye; the snout is rounded and overhangs the mouth which is subterminal. The pharyngeal teeth (0, 4-4, 0) are not hooked and have a distinct grinding surface. There is one dorsal fin with eight rays originating slightly in advance of the origin of the pelvic fins which have eight rays, but sometimes seven. The caudal fin is forked; the anal fin originates behind the posterior margin of the depressed dorsal and usually has eight rays, sometimes nine [eight in Alberta (Nelson and Paetz 1992)]; the pectoral fins are relatively short with 15 or 16 rays. The scales are cycloid with eight to 11 long radii; there is a complete lateral line of 38 to 49 scales [36 to 40 in Alberta specimens (Nelson and Paetz 1992)]. The peritoneum is black and the elongate intestine is coiled on the right side; vertebrae number 36 to 38 (see Scott and Crossman 1973; Trautman 1957), but 39 to 41 in Alberta specimens (Nelson and Paetz 1992).

Small nuptial tubercles may be found on the head, back, sides, and on the fins of breeding individuals (sparse on females, more numerous on males). Both sexes are silvery in colour, hence the common name, with a broad, slaty mid-dorsal stripe. Alberta specimens are brownish-yellow dorsally and silver laterally with no obvious lateral band, but dusky spots may be present (Nelson and Paetz 1992). During spawning the males are light yellow along the sides and the lower fins (Scott and Crossman 1973; Trautman 1957).

Distribution

This is a species of the backwaters of large plains streams found in the Mississippi River basin (Figure 2) from the mouth of the Ohio River north to the Missouri Basin and the Milk River in Montana (Pflieger 1980).

In Canada, the Western Silvery Minnow has been found only in southern Alberta (Figure 3) where it is known from the South Saskatchewan River and seven sites on the Milk River [Pflieger 1980; Scott and Crossman 1973; ROM and UAMZ (University of Alberta Museum of Zoology, Edmonton, Alberta) Collections]. It was first collected in Alberta from the Milk River in 1961 (UAMZ 5320), but the first published records were those of Willock (1968) also taken from the Milk River. Henderson and Peter (1969) also report on one specimen 93 mm S.L. taken from the South Saskatchewan River in 1963. They (Henderson and Peter 1969) suggested that the species had invaded the South Saskatchewan River from the Missouri system. No recent collections of the species have been made from the South Saskatchewan River (Nelson and Paetz 1992).

Protection

In the U.S. the species is considered of Special Concern in Wyoming (Johnson (1987).

In Canada, the fish are not subject to any protected status and could not qualify for general protection under Habitat Sections of the Fisheries Act (not commercial species). General protection could be

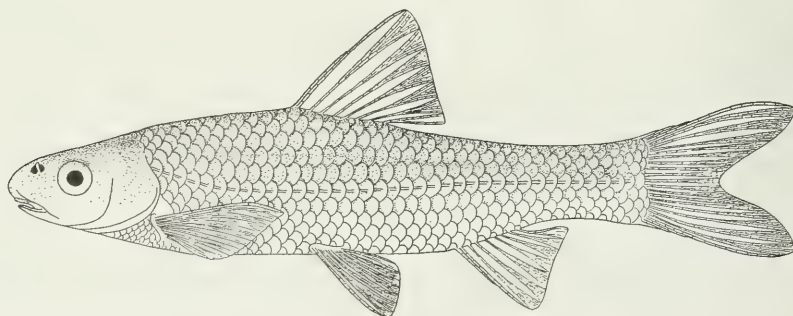


FIGURE 1. Western Silvery Minnow, *Hybognathus argyritis* (\approx 8 cm S.L.).

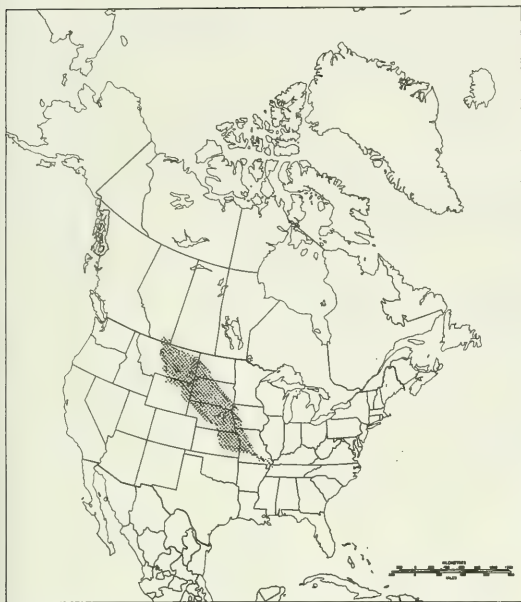


FIGURE 2. North American distribution of the Western Silvery Minnow, *Hybognathus argyritis* (after Scott and Crossman 1973; Pflieger 1980).

afforded, if required, under Alberta provincial wildlife legislation. The species is considered of special concern in Alberta (Johnson 1987).

Population Sizes and Trends

The species is known only from from one collection on the South Saskatchewan River and seven sites on the Milk River in southeastern Alberta. The species was first collected in Alberta from the Milk River in 1961 (UAMZ 5320) and subsequent collections between 1971 and 1976 verified its presence at a further six sites along the Milk River (UAMZ 2846, 3335, 3234, 3241, 3244, 3548.1, 3838.1). The number of specimens collected at each site varied from one to 26 and one site was visited in 1974 (UAMZ 3548.1) and again in 1976 (UAMZ 3838.1), 26 specimens were taken in 1974 and 2 in 1976, apparently it has not been looked for since. The only known record from the South Saskatchewan River is that reported by Henderson and Peter (1969) and it has not been found there since. Nelson and Paetz (1992) indicate the need for further specimens from the South Saskatchewan River before recognition of its establishment there.

There is no information available to establish population sizes or trends. The species appears to be native to the Alberta fauna and has, no doubt, been there for some time, previously going unnoticed or perhaps misidentified as the Brassy Minnow as it was first described by as *Hybognathus argyritis* by C. P.

Girard in 1856 from specimens collected from the Milk River in Montana (Nelson and Paetz 1992). Willock (1968) hypothesized that the species may have been more abundant in upper reaches of the Milk River prior to 1900. Increase turbidity resulting from channelling of irrigation water into the Milk River in the early 1900s may have caused a decline in the population numbers of the species in its Alberta range. The recovery of the river and its vegetation following cessation of this practice has permitted repopulation well into Alberta (Willock 1968).

Willock (1968) provided a hypothesis of the probable history of its occurrence in Alberta and in the Hudson Bay Watershed (South Saskatchewan River). Following deglaciation temporary links existed between the Hudson Bay and Missouri systems and movement in the Missouri system was not difficult. *Hybognathus argyritis* appears to have moved north from a Missouri Refugium (Crossman and McAllister 1985).

Willock (1968) attributed its loss from extensive areas in the United States to increased turbidity and the disappearance of aquatic vegetation and organic debris due to siltation. Apparently it is still abundant where found in the U.S. (Pflieger 1980).

Habitat

There is very little information available on the habitat requirements of the species and none from Canada. Willock (1968) indicated that the ideal habitat of the species is probably quiet waters rich in phytoplankton as suggested by Trautman (1957) for the Silvery Minnows of Ohio. It is a plains species, usually found in the backwaters and pools of larger, northern plains streams (Pflieger 1980). Although sympatric with the Plains Minnow, *Hybognathus placitus*, in the Missouri basin, and the Central Silvery Minnow in the Mississippi basin (Figure 4), it occupies a different niche. The Plains Minnow occupies the open channels of the streams (Gilbert 1980) and can tolerate more turbid waters (Gilbert 1980; Hlohowskyj et al. 1989). The Central Silvery Minnow also occupies the backwaters and pools, but usually in smaller streams than those where the Western Silvery Minnow may be found (Pflieger 1980a,b), and is less tolerant of turbid conditions than either of the other two species (Hlohowskyj et al. 1989).

Trautman (1957) indicated that both the Western and Eastern Silvery Minnows were most abundant in areas of little or no current, where the waters are rich in phytoplankton and the gravelly, sand, muck or debris covered bottom are not covered by silt. He (Trautman 1957) also found that spawning only occurs where the rate of bottom siltation is low.

Like the Central and Eastern Silvery minnows spawning probably occurs in heavily vegetated backwaters in slower moving reaches of the streams (Scott and Crossman 1973; Ramshaw and Mandrak 1998).



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FIGURE 3. Canadian distribution of the Western Silvery Minnow, *Hybognathus argyritis*.

The young of the Eastern Silvery Minnow appear in small schools along the shore in the emergent vegetation about two weeks post-hatch (Raney 1939).

General Biology

The biology and ecology of this species have not been studied, but are probably similar to other species of *Hybognathus* (Pflieger 1980b). The following discussion is drawn from information on the Central and Eastern Silvery minnows and the Plains Minnow after Scott and Crossman (1973), Gilbert (1980) Pflieger (1980a,b), and Ramshaw and Mandrak (1998).

Reproduction

Raney (1939) provided a detailed description of the reproductive biology of the Eastern Silvery Minnow from a study of populations in Cayuga Lake, New York. Spawning took place in about 0.3 m of water in late April and early May in heavily vegetated backwaters in slower moving reaches of the streams. Eddy and Underhill (1974) reported that *Hybognathus nuchalis* (= *argyritis*) spawns in

May and June in Montana. The eggs were about 1 mm in diameter, non-adhesive and egg number varied with female size, varying from 2000 in a 60 mm female to 6600 in a 90 mm female. The eggs hatched in six to seven days with the water temperature varying between 13.3°C and 20.5°C. When propagated in ponds, the Eastern Silvery Minnow reached maturity and spawned at age two, and spawned again the following year (Raney 1942).

In Canadian waters, it is believed that the species spawns in May, although no observations have been published (Scott and Crossman 1973). The Central Silvery Minnow appears to have a similar reproductive biology (Forbes and Richardson (1920). Spawning in the Plains Minnow is protracted from April to August (Gilbert 1980) and there is evidence to suggest that the same may be the case for the Eastern Silvery Minnow (Scott and Crossman 1973).

Growth

Newly hatched larvae of the Eastern Silvery Minnow measured 6 mm T.L. and were 38 mm T.L. by July and about 51 mm by August. Females appear

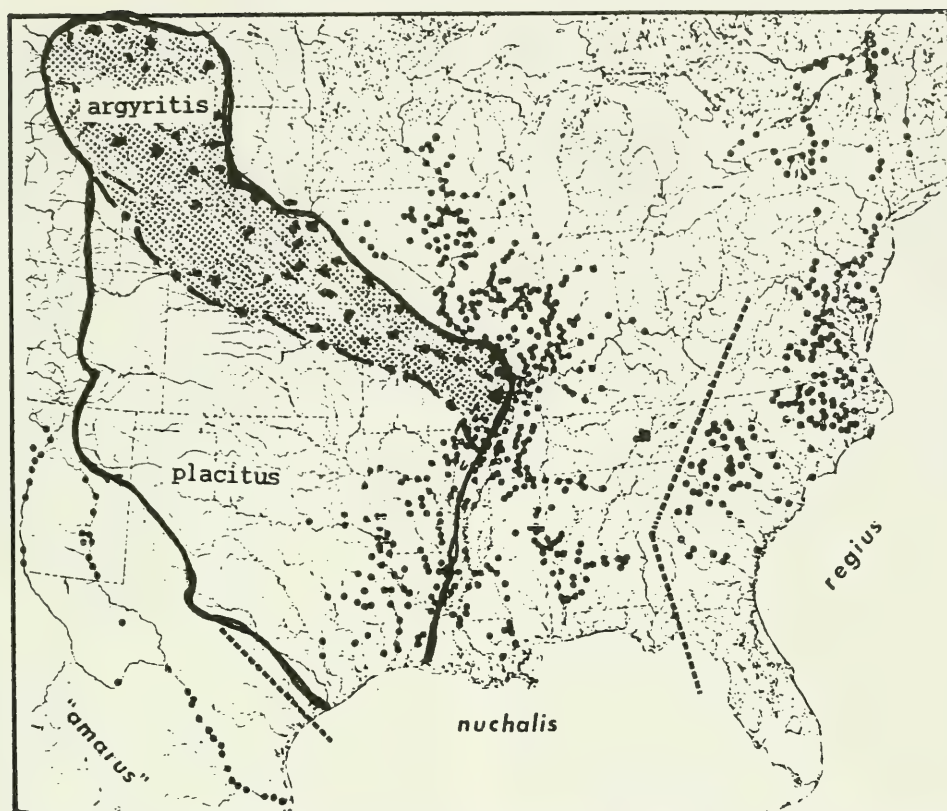


FIGURE 4. Approximate distributions of *Hybognathus argyritis*, *amurus*, *nuchalis*, *placitus* and *regius*. The solid line outlines the range of the Plains Minnow and the dashed line and shaded area the Western Silvery Minnow (modified from Gilbert 1980; Lee 1980; Pflieger 1980a,b).

to spawn at one year of age at about 50 to 55 mm S.L., but males probably do not spawn until their second year (Raney 1939). Larval stages have been described and illustrated by Mansueti and Hardy (1967).

Species Movement

The Eastern Silvery Minnow migrates to spawning grounds in large schools. In Raney (1939) noted that this migration reached its peak in April in New York. Gascon and Leggett (1977) found large postspawning congregations of the Eastern Silvery Minnow in early summer in Quebec.

Diet

The diet of the Eastern Silvery Minnow consists of diatoms, algae, and bottom ooze (Raney 1939; Eddy and Underhill 1974). The Central Silvery Minnow apparently has a similar diet (Pflieger 1989a) as does the Plains Minnow and probably all species of *Hybognathus* (Gilbert 1980). The pharyngeal papillae found in all species of the genus may be an accessory filtering system (to the gill arches) adapted for herbivory (Hlohowskyj et al. (1989).

Gascon and Leggett (1977) outlined the diet of the Eastern Silvery Minnow in Lac Memphrémagog, Quebec. The diet of 0+ fish changed from cladocerans (82% by volume), rotifers (8.4%) and chironomids (7%) to organic detritus (95%) and cladocerans (3%), as the average fork length (F.L.) increased from 32 mm to 44 mm. Individuals greater than 40 mm F.L. fed almost exclusively on organic detritus, except in June when 46% of their diet was cladocerans.

Parasites

Three species of trematodes, one protozoan, and the larval form of the cestode, *Ligula intestinalis*, have been listed as parasites of silvery minnows in North America (Hoffman 1967).

Limiting Factors

Hybognathus nuchalis is sensitive to turbidity and siltation (McAllister and Coad 1974) which are likely causes of population declines in Missouri and Ohio (Pflieger 1971; Trautman 1957). Hlohowskyj et al. (1989) suggested that the finer, densely crowd-

ed pharyngeal papillae of the Central Silvery Minnow may be related to this. The Rio Grande Silvery Minnow, *Hybognathus amarus* (restricted to the Rio Grande drainage), and the Plains Minnow [sympatric with the Central Silvery Minnow in the Mississippi basin (Figure 4)], are often found in turbid habitats. These species have shorter, less crowded papillae and appear to be well-adapted to silty environments (Hlohowskyj et al. 1989).

The Western and Eastern Silvery minnows possess pharyngeal papillae intermediate to those in *Hybognathus nuchalis*, and the Rio Grande and Plains minnows (Hlohowskyj et al. 1989), and are thought to be less sensitive to turbidity and siltation than the Central Silvery Minnow. Massé and Mongeau (1976), for example, relate a decrease in abundance of *Hybognathus regius* (and other fishes) to increased turbidity and siltation resulting from ship-induced wave action in the St. Lawrence River at Montreal. The Western Silvery Minnow and the Plains Minnow usually occupy different habitats, the former being found in backwaters and pools of larger plains streams (Pflieger 1980), and the latter in open, shallow river channels (Gilbert 1980). Trautman (1957) indicated that both the Western and Eastern Silvery Minnows were intolerant of silt and turbidity and felt that increased turbidity was responsible for the extirpation of the Eastern Silvery Minnow in Ohio.

The Milk River flows through short-grass prairie habitat which is subject to continuous erosion producing a high rate of silt deposition. Activity such as channelling or overgrazing could increase the already high rate of siltation and lead to extirpation of the species from its Canadian range (Willock 1968).

Special Significance of the Species

The Western Silvery Minnow is probably an important forage species where abundant, but in the northern parts of the range it may be too rare to be of significance. In the United States it may have some value as a bait fish (Eddy and Underhill 1974), but in Canada it is not commonly used as bait as it does not survive well in a bucket (Scott and Crossman 1973).

The recent appearance in Canada and its distribution and habitat requirements are of interest to science in relation to the zoogeographic history and distribution of species subsequent to the Wisconsin Period of glaciation.

Evaluation

The Western Silvery Minnow has a very limited Canadian range and distribution and is considered a species of special concern in Alberta. It appears that the species may be less sensitive to siltation and turbidity than the Central Silvery Minnow, but like the Eastern Silvery minnow probably requires clear, weedy habitat free of turbidity, pollution or habitat

degradation. The species has obviously been in Alberta for some time, and has been overlooked, or perhaps misidentified as the Brassy Minnow until recently. It may be that the species has a refuge here, but industrial, urban and agricultural activity may result in habitat degradation as has occurred for so many species with similar habitat requirements in the northern U.S. Given the restricted range and apparent rarity of the Western Silvery Minnow in Canada the species should be considered as Vulnerable.

Acknowledgments

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Status of the Chiselmouth, *Acrocheilus alutaceus*, in Canada*

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Coffie, P. A. 1998. Status of the Chiselmouth, *Acrocheilus alutaceus*, in Canada. *Canadian Field-Naturalist* 112(1): 154-157.

The Chiselmouth is a medium-sized cyprinid (10 to 18 cm T.L.), with a unique jaw adaptation which it uses to scrape algae and diatoms from stones, a feeding behaviour from which it derives its common name. The species is confined to the Pacific drainage of the Fraser and Columbia rivers in Canada and the Columbia and Harvey basins of Washington, Oregon, Nevada and Idaho. Although it has a narrow range and scattered distribution in Canada, it is found in several localities and a variety of water body types. There is no information on population sizes and trends, but the species does not appear to be in decline. Likewise, information on the biology, ecology and limiting factors is lacking, although the species could be threatened by habitat loss or degradation in relation to impoundments for hydro-electric development.

La Bouche coupante est un cyprinidé de taille moyenne (10 à 18 cm L.T.) doté de mâchoires uniques permettant de gratter les algues et les diatomées des pierres d'où leur nom commun. Cette espèce est limitée aux bassins des rivières Fraser et Columbia au Canada, et aux bassins des fleuves Columbia et Harvey dans les états de Washington, du Nevada, de l'Idaho et de l'Oregon. On trouve l'espèce dans plusieurs endroits et dans différents types de cours d'eaux au Canada, bien que son habitat est limité et sa répartition est dispersée. Les renseignements quant aux tailles et aux tendances des populations n'existent pas, mais l'espèce ne semble pas être en déclin. Également, on manque d'information sur la biologie, l'écologie et les facteurs limitatifs, quoique l'espèce pourrait être menacée par la perte d'habitat ou la dégradation due au développement d'hydro-électrique.

Key Words: Chiselmouth, *Acrocheilus alutaceus*, Bouche coupante, British Columbia, rare species.

The Chiselmouth, *Acrocheilus alutaceus* Agassiz and Pickering, 1855, is a medium-sized cyprinid with a unique adaptation of the lower jaw which gives rise to its common name. Beyond the study by Moodie (1966), little is known about the species which has a restricted and scattered Canadian range (see Scott and Crossman 1973). Considered a rare species in British Columbia (Cannings 1993) the species is of interest to the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). This report summarizes the available information on the species based largely on the accounts of Scott and Crossman (1973) and Cannings (1993).

Description

The Chiselmouth (Figure 1) is 15 to 18 cm in Total Length (T.L.) cyprinid with an elongated, moderately compressed body. The species has a unique mouth - the jaws have large, straight horny plates, which are conspicuous and sharp and enable the fish to use a specialized diet of algae and diatoms scraped from rock (Slastenenko 1958; Carl et al. 1967; Scott and Crossman 1973). Scott and Crossman (1973) provided a detailed description of the species. The Chiselmouth is drab in colour, with dark brown above and lighter sides covered with small black spots. The ventral surface is lighter still

and young fish have a poorly defined dark spot at the base of the caudal fin. Some fish may show orange colouration in the axis of the pectoral and pelvic fins.

Distribution

The Chiselmouth is largely confined to the Pacific drainage of the Fraser and Columbia rivers (Figure 2). In the United States, it is found in the Columbia drainage in Washington and the Harvey Basin of the Malheur Lake drainage in Oregon, Nevada and Idaho (Scott and Crossman 1973; Wydoski and Whitney 1979; Wallace 1980; Sigler and Sigler 1987; Cannings 1993).

In Canada, the Chiselmouth has been recorded only from British Columbia where it has been found in scattered locations in the Columbia River system, Misesezula, Wolfe, Skaha, Gallagher and Tugulnuit lakes (of the Similkameen River drainage), and the Okanagan River of the Okanagan-Columbia system, as well as the Kettle River and Lake Windermere of the Kootenay-Columbia system (Figure 3). It is also known from two distinct locations in the Fraser River system (Figure 3); the Euchiniko and Nazko tributaries of the West Road River in the Fraser system, and Mara Lake in the Shaswap drainage [Carl et al. 1967; Scott and Crossman 1973; Cannings 1993; collections of the University of British Columbia (UBC) and the Royal British Columbia Museum (RBCM)]. Carl et al. (1967) also list the species as

*Indeterminate status assigned by COSEWIC 16 April 1977.

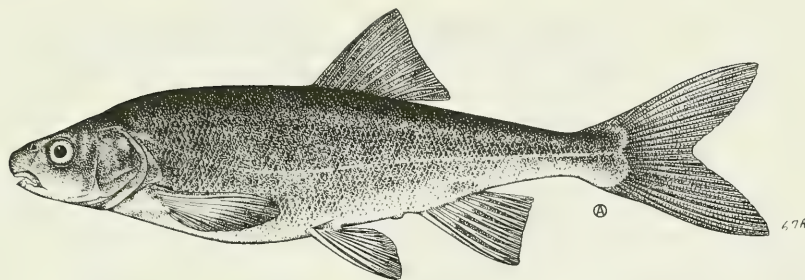


FIGURE 1. Chiselmouth, *Acrocheilus alutaceus* (drawing by A. Odum, from Scott and Crossman 1973 by permission). Male; 633 mm, taken from Missizoula Lake, British Columbia, 24–25 July 1959; UBC. 60–221. Inset shows the small cartilaginous plate of the upper jaw and the hard, chisel-like cartilaginous sheath of the lower jaw.

occurring in Nicola Lake in the Fraser drainage, but this record requires verification. (Cannings 1993).

Protection

The species is not listed as a species of concern in the United States (Johnson 1987). In British Columbia, it has been assigned a Nature Conservancy Global Rating of G5 and a Provincial Rating of S3 and provisionally listed as Blue (rare species, species to watch, *see* Cannings 1993). No specific legislation exists for the protection of the species in Canada. General protection, if required, could be provided under provincial wildlife and endangered species legislation.

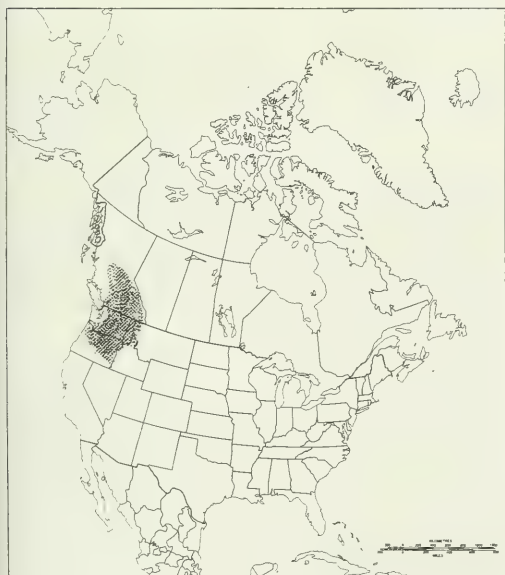


FIGURE 2. North American distribution of the Chiselmouth, *Acrocheilus alutaceus* (from sources cited in the text).

Population Sizes and Trends

There is no information on Canadian populations, other than presence and absence data (e.g., Cannings 1993). There is no evidence on which to base population trends, although Cannings (1993) indicated that there is no evidence of a decline. The species has been recorded from some 12 widely separated localities from six ecosystems (*see* Cannings 1993) of four watersheds. Further inventories are needed to determine the true extent of the range.

Habitat

Wallace (1958) described this as a species of slow flowing streams and lakes. Wydoski and Whitney (1979) reported the habitat as warmer sections of streams and moderately fast to fast water. In British Columbia, the species occupies the relatively warm waters of small creeks, backwaters of large rivers, small lakes and large lakes (Cannings 1993).

General Biology

There is very little information on the biology or ecology of the Chiselmouth. Moodie (1966) provided the only account of the species in Canada. Spawning in lake populations occurs up to 1.5 km upstream in tributary streams, usually in late June and early July at temperatures of 17°C or higher. Spawning was not observed, but eggs were found on the bottom and buried among rocks. The average egg count (for six females) was 6200 (Moodie 1966).

The larvae are about 8.1 mm at birth, from the time of yoke absorption to a length of 15 mm they are difficult to distinguish from other cyprinids. Larger (than 15 mm) fish can be distinguished by the characteristic mouth. Data on growth is lacking, but males probably become sexually mature at age three, females at age three or four. The maximum age found by Moodie (1966) was six when fish length is about 22.5 cm.

Young fish (up to 10 cm) feed mainly on surface insects. The adult diet is restricted to diatoms



FIGURE 3. Canadian distribution of the Chiselmouth, *Acrocheilus alutaceus* (after Cannings 1993).

obtained by scraping filamentous algae and diatoms from rocks and other substrates with the chisel-like lower jaw (Scott and Crossman 1973). Large amounts of filamentous algae and diatoms are consumed, but Moodie (1966) found no evidence that the algae was digested and concluded that diatoms were the major food.

Limiting Factors

The apparent requisite for water temperatures above 17°C may limit the distribution in the cooler streams of higher altitudes in British Columbia.

Young fish have a diet similar to that of young Squawfish (*Ptychocheilus oregonensis*). Competition for food at this stage of the life cycle might be limiting in some areas where larger concentrations of Squawfish occur in the same watersheds (see Scott and Crossman 1973).

Bangham and Adams (1954) found fish from British Columbia infested with the nematode *Rhabdochona cascadiella*, the trematodes *Posthodiplostomum minimum* and *Neascus* sp., and Gyrodactyloidea. Hoffman (1967) provides information on other parasites, but no evidence as to whether they are limiting.

The Chiselmouth is not known from reservoirs in British Columbia. Impoundments may prevent upstream movement and the species does not survive in deeper waters above the dams (Cannings 1993). Slatick and Barham (1985) found that Dennil

Fishways of 20 m or more in length prevent upstream movement of cyprinids, including Chiselmouth, but shorter fishways could be passed.

Special Significance of the Species

The species is of little or no economic importance, but is of biological interest because of the unique adaptation of the jaws and utilization of primary productivity. At one time, the species was apparently used by aboriginal people for food (La Rivers 1962).

Evaluation

There is very limited information on this species, its scattered distribution or possible threats. It appears to be a rare member of the British Columbia fauna, but it is not possible to determine at this time whether or not the species is at risk in Canada.

Acknowledgments

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Notes

A Notable Range Extension for the Globally Rare Endemic Plant, *Cryptantha shackletteana* L.C. Higgins, in East-central Alaska

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Roland, Carl A., and Mary B. Cook. 1998. A notable range extension for the globally rare endemic plant, *Cryptantha shackletteana* L.C. Higgins, in East-central Alaska. *Canadian Field-Naturalist* 112(1): 158–160.

A new location in the Mentasta Mountains, Alaska, is reported for *Cryptantha shackletteana*, a globally rare endemic known previously from two localities on the Yukon River in Alaska. The new locality is 240 km to the southwest of the Yukon River sites, and is located in a different physiographic province; the Alaska Range. The new locality suggests that this plant was formerly more widespread in Alaska than it is today.

Key Words: *Cryptantha shackletteana*, *Cryptantha spiculifera*, rare plants, endemic species, range extension, Alaska.

A floristic inventory of the Nabesna River valley in Wrangell-St. Elias National Park and Preserve, conducted during June 1996, resulted in the discovery of three populations of the narrowly restricted plant *Cryptantha shackletteana* L.C. Higgins. This species is listed as globally rare by the Alaska Natural Heritage Program (Global Rank: Q1, State Rank: 1) and as a Species of Concern by the U. S. Fish and Wildlife Service (R. Lipkin, personal communication). Previously, it was known from the type locality at Eagle, Alaska, and one other site in close proximity on the Yukon River, 240 kilometers north-northeast of the new locality (Figure 1). The discovery in the Nabesna River valley is significant because it extends the range of this species into the Alaska Range, a physiographic province in which it was not previously known or expected to occur. The new localities also broaden our concept of the species ecological amplitude to include alpine situations (the Yukon River localities are in the lowlands).

The new sites are clustered near the eastern terminus of the Mentasta Mountains, in east central Alaska (62°27.63' N, 142°40.66' W; Figure 1) and are located on a steep, east to west trending ridge that lies north of Totschunda Creek and west of the Nabesna River. Bedrock in the area is composed of marine sedimentary rocks (Ritter 1971).

Specimens are deposited at the Herbarium of the University of Alaska Museum (ALA). Data for these collections are:

ALASKA, Wrangell-St. Elias National Park, slopes N of lower Totschunda Creek at SE terminus of Mentasta Mts., Nabesna B4 Quadrangle, 62°27.63' N 142°40.66' W, elevation 1275 m, 28° slope, 130°

aspect, plants were scattered in reddish calcareous gravel on moderate southeast to southwest facing slopes with *Anemone drummondii*, *Calamagrostis purpurascens*, *Cnidium cnidiifolium*, *Delphinium glaucum*, *Crepis nana*, *Oxytropis splendens*, *O. viscida*, *Potentilla nivea*, and *Senecio ogoturukensis*, *C. Roland* 96-284, 24 June 1996, (ALA V122496); Slopes N of lower Totschunda Creek at SE terminus of Mentasta Mts., 62°27.98' N, 142°41.49' W, 1371 m elevation, 10° slope, 197° aspect, plants were scattered on rock outcrops, stable slide debris and barren



FIGURE 1. The distribution of *Cryptantha shackletteana*. Map shows the locations of type locality on the Yukon River (■), the newly discovered locality in the Mentasta Mountains (●), and the *Cryptantha* locality on the Chukotka peninsula reported by Tolmachev and Yurtsev (○).

gravel on southwest slopes with *Androsace chamaejasme*, *Artemisia hyperborea*, *Melandrium apetalum*, and *Zygadenus elegans*, Carl Roland 96-295, 24 June 1996, (ALA V122497); Second ridge N of lower Totschunda Creek, at SE terminus of Mentasta Mts., 62°28.23' N, 142°40.52' W, 1244 m elevation, 36° slope, 161° aspect, plants scattered in dry, barren calcareous gravel and rock outcrops on southern exposures along an east trending ridge with *Anemone drummondii*, *Braya humilis*, *Calamagrostis purpurascens*, *Elymus trachycaulus*, *Hedysarum alpinum*, *Linum lewisii*, *Oxytropis splendens*, and *Potentilla nivea*, Carl Roland 96-369, 24 July 1996, (ALA V122498).

Cryptantha shackletteana is the only native representative of its genus in Alaska. It has been considered a vicariant of *Cryptantha spiculifera* (Payson) Piper, a species common over 2000 km to the south in the Great Basin states (Higgins 1969; Cronquist et al. 1984). It is weakly differentiated from that taxon in having setose hairs arising from conspicuous pustules only on the undersides of the leaves, in contrast to both sides for *C. spiculifera* (Higgins 1969). Additionally, Higgins (1969) stated that *C. shackletteana* has longer and narrower leaves, a more capitate inflorescence, and nutlets that are longer and narrower than those of *C. spiculifera*.

The taxonomic validity of *Cryptantha shackletteana* at the species level is unclear. Hultén (1968) treated what was later the type material of *Cryptantha shackletteana* as *C. spiculifera*. Batten et al. (1979*), reviewed specimens from the Yukon River localities and suggested that the morphological variation they observed was indistinguishable from the description of *C. spiculifera*. We examined specimens from all three Alaskan localities as well as a series of specimens of *C. spiculifera* from the Great Basin and observed consistent differences between plants from the two areas in the density and location of pustulate hairs on the leaves (as was noted by Higgins in 1969).

While taxonomic questions persist, we agree with previous authors (Batten et al. 1979*; Cody 1996; Murray 1981*; Murray and Lipkin 1987; Parker 1995*) that it is prudent to accept Higgins' (1969) treatment due to the morphological discontinuities in the specimens from the two areas, the profound disjunction of the Alaskan distribution of *C. shackletteana* from the range of *C. spiculifera* and its extreme rarity in Alaska.

In the upper Yukon River valley *C. shackletteana* is found in an association that includes several rare and disjunct plants. Two of these taxa, *Eriogonum flavum* var. *aquilinum* and *Erysimum angustatum* are also close vicariants of common Great Basin species

that have major gaps separating them from the range of their southern relatives (Hultén 1968). Similarly, the subarctic ranges of *Phacelia sericea* and *Phlox hoodii* are disjunct from their main ranges in the Great Basin and Rocky Mountains.

This unique association of rare plants was first documented by Shacklette in 1966. Since that time, additional populations of the rare species associated with *C. shackletteana* have been found during floristic surveys of areas with similar habitat characteristics (Batten et al. 1979*; Murray et al. 1983; Howenstein 1994; Roland 1996). Most of the new localities are limited to the upper Yukon River valley of eastern Alaska, although *Eriogonum flavum* var. *aquilinum* has been found on bluffs along the Porcupine River in Alaska (Howenstein 1994; Roland 1996). In contrast, the range of *C. shackletteana* has not been extended beyond the two populations close to Eagle, Alaska. This is noteworthy because of the concerted effort to locate additional populations of this taxon, including status surveys conducted for the U.S. Fish and Wildlife Service (Murray 1981*; Parker 1995*).

Intriguingly, however, Tolmachev and Yurtsev (1980) reported a single locality for a perennial *Cryptantha* on the southeastern coast of the Chukotka peninsula in Russia (see Figure 1). They assigned this specimen to *C. spiculifera* based on Hultén's (1968) description. They were unable to confirm their identification with herbarium reference material of *C. spiculifera*, because there are no specimens in Russian herbaria (Tolmachev and Yurtsev 1980), and no North American botanists have seen the Russian specimen (D. Murray, personal communication).

The coexistence of small, localized populations of *Cryptantha* and other essentially temperate-zone species in a limited area of interior Alaska and Yukon prompted the hypothesis that these species migrated north through a narrow dispersal corridor during the warm, dry Hypsithermal period of the Holocene, 9000-6000 years before present (Murray et al. 1983). The warm, dry, climate of the Hypsithermal may have resulted in the contraction of forests and an expansion of potential habitat for shade-intolerant xerophytes like *Cryptantha*, *Eriogonum*, and *Phacelia*. Indeed, a *Juniperus*-rich stratum of fossil pollen dating to this period has been observed in palynological studies from interior Alaska and has been interpreted as signifying an expansion of open vegetation on the landscape (Edwards and Barker 1994).

The presence of *Cryptantha* in the alpine zone of the Mentasta Mountains, a considerable distance from the putative dispersal corridor, complicates our understanding of its history, as does the possible Russian locality. It may be that this species has been a part of the subarctic flora for a longer time than has been supposed. This species is not particularly adapted for long distance dispersal. Consequently, it is

*See Documents Cited section.

unlikely that its subarctic range is the result of repeated long-distance dispersal events. More likely, the isolated populations found in Alaska are the result of the fragmentation of a formerly more extensive range. While the expansion of *Cryptantha* from temperate latitudes and then across major drainages within interior Alaska during a brief period of the Holocene is plausible, it is doubtful that a species capable of such a striking northward expansion would subsequently all but disappear from the landscape within a relatively short time. Furthermore, if the Russian locality is *bona fide*, this species probably migrated to Chukotka during a period when the Bering land bridge was exposed; i.e., during a glacial interval of the Pleistocene.

Our new understanding of the geographic and ecological distribution of *C. shackletteana* requires a reconsideration of its history in Beringia. It is probable that it has been in Beringia since before the mid-Holocene. In fact, the Beringian landscape during Pleistocene glaciations would have presented fewer barriers to the dispersal of *Cryptantha* within its subarctic range because forests were essentially absent from the landscape (see Matthews 1982; Ritchie 1984). The distribution of this plant is probably the result of a history that includes more than one cycle of range expansion and subsequent decay.

The discovery of *C. shackletteana* in the Alaska Range stimulates questions concerning its history and the biogeographic implications of the group of temperate North American vicariants with which it is associated. The distribution of a species alone, however, is an insufficient basis for making conclusive inferences about its history and past distribution. Further study of the ecotypic, genetic and morphological differentiation within and among extant populations of *Cryptantha spiculifera* sensu lato would help to resolve some of the taxonomic and biogeographic questions raised by its distribution.

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An Apparent Case of Between-Brood Sibling Competition in Chestnut-collared Longspurs, *Calcarius ornatus*

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Hill, Dorothy P. 1998. An apparent case of between-brood sibling competition in Chestnut-collared Longspurs, *Calcarius ornatus*. Canadian Field-Naturalist 112 (1): 161–163.

I report observations consistent with the interpretation that a Chestnut-collared Longspur (*Calcarius ornatus*) fledgling from a first brood begged for and received food from its parents at a their second brood nest. All five nestlings in the second brood subsequently died and starvation appeared to be the major factor contributing to their deaths. This is the first reported case of apparent between-brood sibling competition in a passerine species and it fits the criteria of a parent-offspring conflict.

Key Words: Chestnut-collared Longspur, *Calcarius ornatus*, sibling competition, parent-offspring conflict, multiple broods.

Within-brood sibling competition is common among birds. Death of younger or smaller offspring often is attributed to larger or older siblings through competition for food, trampling, ejection of siblings from the nest, or overt aggressive attacks (reviewed by Mock et al. 1990). Debate persists as to whether sibling competition represents the phenotypic expression of an underlying genetically based, parent-offspring conflict (Trivers 1974), or whether the outcome of such competition is in keeping with the brood-reduction strategies of parents (Drummond 1993; Forbes 1993). Siblings compete with one another for food by begging, which involves vocalizing, jockeying for position within the nest, gaping, and stretching their necks towards the parents. Mock and Forbes (1992) suggested that, in order to demonstrate that nestling begging is a manifestation of parent-offspring conflict, it must be shown that begging induces parents to invest in offspring at levels detrimental to their own fitness. Here, I report the first observation of apparent between-brood sibling competition in a passerine species that appears to fit those criteria.

Chestnut-collared Longspurs (*Calcarius ornatus*) are small (20 g) grassland passerines that breed in the native short- and mixed-grass prairie regions of North America. Longspurs nest from the end of April to the beginning of August and typically raise two broods within the same breeding season (Hill and Gould *in press*). Females build a new nest for each clutch, and the broods overlap such that fledglings from first broods are still dependent on their parents for food when second clutches are initiated (Fairfield 1968). The male provides the majority of fledgling care while the female prepares for the second clutch (Harris 1944; Hill and Gould *in press*). Pair-bonds persist throughout the breeding season (Harris 1944; Hill and Gould *in press*), and young remain on their natal territory well past indepen-

dence (Hill and Gould *in press*).

Individually colour-banded longspurs were observed within a 600 m × 700 m grid located in the Remount Community Pasture near Bindloss, Alberta (50° 40' N, 110° 10' W). I found nests by dragging a 30-m rope over the pasture to flush incubating females and by observing female longspur behaviour. Once located, nests were visited daily until the young left the nest or the nest failed. Young were weighed, measured, and banded with a unique combination of three plastic coloured leg bands and a numbered aluminium U.S. Fish and Wildlife band. As part of a larger study examining parental care, hour-long focal nest observations were conducted on nestling day 6 (from day 1 = hatch day).

On 1 May 1994, a banded female initiated her first clutch, which contained four eggs. Three of the eggs hatched 16 May and the fourth 18 May. Young were banded 23 May when the largest nestling had a wing length of 33 mm (siblings' measurements ranged from 30 to 32 mm) and a mass of 13 g (siblings' masses were 12 g, 13 g, and 13 g). On 26 May, all four young left the nest. On 3 June, the female initiated her second clutch, which ultimately contained five eggs. Her banded mate was observed feeding two of the first-brood fledglings on 11 June while the female was incubating the second clutch. At that time, both fledglings were observed pecking at the ground and one, the largest at banding, successfully caught an insect.

Four eggs from the second clutch hatched on 18 June and the fifth hatched 19 June. By that time there was no evidence that the male was still feeding the first-brood fledglings. Typically, offspring are fed for up to 14 days after leaving the nest (Harris 1944). The longest I have observed a male feeding a fledgling is 22 days after leaving the nest, while his mate was incubating the second brood (unpublished data). In three years of study, I have never observed

longspur parents feeding first-brood young up to the time their second brood hatched ($N = 35$ second broods), although they still uttered alarm calls when fledglings were approached by humans. Furthermore, parents often responded aggressively to begging fledglings once young were present in the second-brood nest (personal observation).

A focal nest observation conducted at the second-brood nest on 23 June was unusual for two reasons. First, loud begging vocalizations were heard from the vicinity of the nest, which is atypical because, although Chestnut-collared Longspur fledglings often beg loudly, day 6 nestlings are generally inaudible from the 20–40 m distances from which nest observations were conducted. Secondly, the combined hourly number of feeding trips made by the parents during that observation was much higher than the average: 21 compared to a mean of 11.6 (± 4.5 SD; $N = 52$ focal nest observations). At the end of the observation period, the nest was approached and one of the first-brood fledglings, the largest from the first brood, flushed from beside the nest. The following day, the second brood young were banded. Their masses were typical for day 7 nestlings (7–13 g) and no external parasites were found on any of the young. The smallest nestling (7 g) was found dead in the nest 25 June and the next smallest (10 g) died 26 June. These two deaths were not completely unexpected given that those nestlings were the smallest two in the brood and brood reduction is fairly common in this species (personal observation). There is no indication that brood reduction is more common in second than in first broods, and brood size on day 6 was similar in first and second broods (unpublished data). However, on 29 June, 11 days after hatching, when most Chestnut-collared Longspur young leave the nest (Harris 1944; Fairfield 1968), the remaining three young were found dead.

Bodies of those three nestlings were collected and autopsy revealed that their crops were empty and their gizzards contained only small quantities of grasshopper legs. Because I monitored nests daily, the young could not have been dead more than 24 hours. Masses of the dead young at collection were only 5 g, 5 g, and 4 g, which represents an approximate 60% reduction from their masses attained five days previously at banding on 24 June. Although some of the mass loss probably resulted from desiccation, the autopsies suggest that despite the high number of feeding trips made by the parents during the 23 June nest observation, the young were not fed for several days and subsequently starved. Both parents were observed on the territory up to the day the nestlings were found dead. No evidence of injury was found on any of the young.

The dead nestlings were examined for ectoparasites. The nestling that had the highest parasite load had six *Protocalliphora metallica* (order: Diptera,

family: Calliphoridae) blowfly larvae on its wings and back. One other nestling had two of these larvae and the other had none. *Protocalliphora* larvae feed intermittently on nestling blood (Bennett and Whitworth 1991). Cases of these parasites causing nestling death are rare and are usually attributed to a combination of stresses including starvation or dehydration (Gold and Dahlsten 1983). Gold and Dahlsten (1983) found that the blowfly larvae themselves survive better in nests that successfully fledge young and suggested that it would be maladaptive for *Protocalliphora* to kill its nestling hosts. This strongly suggests that parasites alone did not kill these nestlings and that starvation was the principal factor in their deaths. Of 254 nests monitored in three years, this was the only nest at which starvation of an entire brood was observed. Furthermore, the observations made during the focal nest watch suggested that the first-brood fledgling was begging at the second-brood nest and, thus, at least attempting to compete with its second-brood siblings. Assuming that some of the feedings by adults were received by that fledgling, it is likely that this contributed to the deaths of the second brood chicks.

Ricklefs (1966) was among the first to suggest that begging represents competition between siblings, as well as communication between parents and offspring. Trivers (1974) proposed that there is a genetic basis for parent-offspring conflict because parents should value all of their offspring equally whereas each offspring should value itself more than its siblings. Thus, it has been suggested that begging is a phenotypic manifestation of the underlying genetically based, parent-offspring conflict (e.g., Harper 1986). However, parental birds appear to promote brood reduction through incubation regimes that create size and age hierarchies within broods. Therefore, it is unclear whether within-brood sibling competition complements or conflicts with parental fitness (Mock and Forbes 1992; Drummond 1993; Forbes 1993).

In contrast, between-brood sibling competition clearly represents a parent-offspring conflict. I suggest that my observations are consistent with the explanation that the first-brood fledgling, although capable of feeding itself, manipulated its parents to continue feeding it by begging at the second-brood nest and thus "posed" as a nestling. Although this behaviour is rare, it suggests that double-brooded avian species, particularly those with brood-overlap, may prove valuable subjects in unravelling the complexities of begging competition and its relationship to parent-offspring conflict.

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Mountain Tassel-flower, *Soldanella montana* (Primulaceae), in Mount Robson Provincial Park, British Columbia

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Scotter, George W., and Barbara Zimmer. 1998. Mountain Tassel-flower, *Soldanella montana* (Primulaceae), in Mount Robson Provincial Park, British Columbia. *Canadian Field-Naturalist* 112(1): 163–164.

Mountain Tassel-flower (*Soldanella montana*) is reported from Mount Robson Provincial Park, British Columbia. This is the first report of this European plant from a natural area in Canada. The plant was likely introduced accidentally by a park visitor.

Key Words: Mountain Tassel-flower, *Soldanella montana*, introduced, Mount Robson Provincial Park, British Columbia.

While hiking in Mount Robson Provincial Park in early June of 1994, Barbara Zimmer and her sister, Marion Fox, found an interesting plant that they could not identify. Zimmer photographed the single plant that was in flower, and slides were sent to George Scotter for identification. About that time, Fox saw a picture of Mountain Tassel-flower (*Soldanella montana*) in a horticultural magazine (Fischer 1993) and suggested that it might be the plant they had seen and photographed.

In early June of 1995, Zimmer returned to the site and found three plants in flower. Scotter and Zimmer visited there on 25 July 1995 to inventory the number of plants present. Twenty-eight plants

with three seed stalks were found in a single small colony.

With permission from Mount Robson Provincial Park, Scotter and Zimmer collected three flowering plants on 4 June 1996. At that time there were 33 plants at the site, and eight were in flower. The number of nodding, lavender-blue flowers ranged from one to four per stalk. Both the calyx and corolla were 5-parted. The corolla was campanulate with fringed lobes to 1.5 cm long. Leaves were orbicular, up to 6 cm across, deeply cordate at the base, and long-petioled (Figure 1). The petioles were glandular and hairy. The flower stocks were 9 to 22 cm tall.

The collection site is on the right hand side of the



FIGURE 1. Line drawing of a Mountain Tassel-flower as found in Mount Robson Provincial Park, British Columbia.

Berg Lake Trail, about 0.5 km from the parking lot in Mount Robson Provincial Park. The plants were growing about one meter off the heavily used trail near the Robson River (53° 03' 15" N, 119° 12' 50" W) at an elevation of approximately 880 m.

By using a number of European floral keys, Scotter identified the collected material as Mountain Tassel-flower. That identification was later confirmed by W. J. Cody, Eastern Cereal Crops and Oilseed Research Centre, Agriculture and Agrifood Canada, Ottawa; Adolf Ceska, British Columbia Conservation Data Centre, Victoria; and Josef Holub, Botanical Institute CAS, Czech Republic.

Associated plant species at the site include Subalpine Fir (*Abies lasiocarpa*), Western Hemlock (*Tsuga heterophylla*), Western Red Cedar (*Thuja plicata*), Sitka Alder (*Alnus crispa* ssp. *sinuata*), Oval-leaved Blueberry (*Vaccinium ovalifolium*), Bunchberry (*Cornus canadensis*), One-sided Wintergreen (*Orthilia secunda*), Twinflower (*Linnaea borealis*), Oak Fern (*Gymnocarpium dryopteris*), Step Moss (*Hylocomium splendens*), and Freckle Pelt (*Peltigera aphthosa*). The site was cool and shaded; the plants received direct sunlight only for an hour or so in the late afternoon. The underlying soil contained numerous rounded stones, likely deposited by the Robson River during a flood.

Mountain Tassel-flower is native to the foothills of the Alps and Carpathian Mountains of Europe (Hegi 1927; Polunin 1969; Meyer 1985). We believe that Mountain Tassel-flower is a recent addition to the flora of Mount Robson Provincial Park. Our hypothesis is that seeds of the plant were hitchhikers on the tread of a hiker's boot. The nearness of the site to the parking lot and its location on the downhill side of this heavily used trail are consistent with that premise.

Approximately 32% of the hikers on the Berg Lake Trail are from abroad, with the vast majority of that percentage from Europe (Wayne Van Velzen, Mount Robson Provincial Park Area Manager, personal communication). Water could have carried seeds from the trail down the slope to the collection site. It could have been seeded by some visitor, but that is unlikely since the plant seems limited to one location. Although Mountain Tassel-flower is grown as a cultivated plant, it is unlikely to be a garden escape. The site is well removed from the nearest garden, and none of the local nurseries contacted grow the plant for sale.

The plants, however, show some variation that may be a product of introgression that is taking place in North American gardens between Mountain Tassel-flower and Snowbell (*Soldanella carpaticea*). This may indicate that our plants originated from garden seeds rather than from seeds of the natural populations (Adolf Ceska, personal communication). Regardless of how this strikingly beautiful member of the Primulaceae originated in Mount Robson Provincial Park, it appears to be thriving in its new environment.

Specimens (Scotter 101,911 and 101,911A) were deposited in the herbarium of the Biosystematics Research Centre, Agriculture Canada, Ottawa (DAO) and the herbarium of the Royal British Columbia Museum (V).

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A Migration of Adult Army Cutworms, *Euxoa auxiliaris* (Grote) (Lepidoptera: Noctuidae) at High Elevation

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Hendricks, Paul. 1998. A migration of adult Army Cutworms, *Euxoa auxiliaris* (Grote) (Lepidoptera: Noctuidae) at high elevation. *Canadian Field-Naturalist* 112(1): 165–166.

A large migration of adult Army Cutworms, *Euxoa auxiliaris* (Grote) crossed the Beartooth Plateau above treeline (3000–3360 m elevation) on the Montana-Wyoming border during 2–8 July 1989. Thousands of moths were in flight throughout the daylight hours, and many paused to nectar from willow (*Salix nivalis* and *S. glauca*) flowers. Density of moths on *S. nivalis* mats was about 30 m⁻² on 6 July, during peak abundance. Migratory movement corresponded to a temporary warming period in the alpine. Flocks of up to 75 Common Ravens (*Corvus corax*) appeared during the migration to feed on moths, and some remained in the alpine two weeks after the moth migration had passed. No diurnal migration of moths occurred on the Beartooth Plateau during July 1983, 1984, 1987, 1988, but a similar movement was noted in July 1963. Moths were probably in transit to summer aggregation sites in the nearby Absaroka Mountains of northern Wyoming.

Key Words: Army Cutworm, *Euxoa auxiliaris* (Grote), Common Raven, *Corvus corax*, insect migration, alpine, Wyoming.

The Army Cutworm, *Euxoa auxiliaris* (Grote), a noctuid species widely distributed in western North America from Canada to Mexico (Cook 1927; Pruess 1967), has been of considerable economic interest as a pest of cereal crops. On the Great Plains, adult moths disappear by early summer following spring emergence, and reappear in late summer. Formerly, it was assumed that adults aestivated until fall (e.g., Cook 1927). Now it is known that adult moths in some regions undertake massive migrations in early summer to adjacent mountains (Pepper 1932; Pruess 1967), where they feed on nectar and accumulate fat stores (Pruess 1967). A second mass movement occurs in late summer when adults return to the Great Plains to mate and lay eggs. More recently, additional interest in the biology of Army Cutworms developed after wildlife biologists documented that aggregations of adult moths above treeline in the Rocky Mountains are important ephemeral food during summer for some populations of Grizzly Bears, *Ursus arctos horribilis* (Chapman et al. 1955; Craighead et al. 1982; Servheen 1983; Mattson et al. 1991; D. White personal communication).

Most of our knowledge of the biology of Army Cutworms has been acquired on the prairies, where egg-laying occurs, or at summer aggregation sites above treeline. Descriptions of migratory movements while moths are in transit to summer aggregation sites are largely lacking (but see Pepper 1932), and little is known about migrations once they are in the mountains at high elevations.

During 2–8 July 1989 I observed a large migration of Army Cutworms cross the Beartooth Plateau (3000–3360 m) at Beartooth Pass (45°00'N 109°30'W) near the border of Carbon County, Montana and Park County, Wyoming. Beartooth Plateau, one of a series of uplifts with extensive

alpine habitat (>200 km²) above 3000 m elevation, has been the focus of several ecological studies of alpine flora and fauna (e.g., Johnson and Billings 1962; Pattie and Verbeek 1966). Thousands of moths were noted throughout the day flying towards the southwest, generally within 10 m of the ground. The migration appeared to peak on 6–7 July, and few Army Cutworms were noted at Beartooth Pass after 9 July.

The migration corresponded to a temporary warming trend above treeline. During the migration (2–8 July) daily temperature maxima and minima (mean \pm SD) at Beartooth Pass were $19.1 \pm 2.0^\circ\text{C}$ and $7.7 \pm 2.1^\circ\text{C}$, respectively, significantly warmer than for the preceding and following seven-day periods (respective maxima and minima were $13.8 \pm 3.7^\circ\text{C}$ and $2.2 \pm 2.6^\circ\text{C}$ for 25 June–1 July, and $16.9 \pm 2.5^\circ\text{C}$ and $4.3 \pm 1.4^\circ\text{C}$ for 9–15 July). Weather for the week preceding and during the migration was sunny and mostly calm, while the week following the migration was accompanied by frequent rain, some graupel and fog. There are no additional data relating migratory activity of Army Cutworms to local climatic conditions at high elevations, so the correlation between timing of migration and weather conditions reported here may have been due to chance.

Thousands of moths paused during migration to nectar from flowering catkins of alpine willow (*Salix nivalis* and *S. glauca*). Density estimates were difficult to make in stands of *S. glauca*, as hundreds of moths would take flight when stands were entered; density of moths on mats of *S. nivalis* between the east and west summits of Beartooth Pass was $30.6 \pm 6.2 \text{ m}^{-2}$ ($n = 10$ plots) on 6 July. Prior to the moth migration, Beartooth Pass was visited frequently by a nesting pair of Common Ravens (*Corvus corax*). Flocks of ravens appeared at the pass on 5 July, during the peak of moth migration, and

remained in the area until 26 July; flock size ranged from 10-75 birds. Ravens were observed on the ground at all hours during the day, feeding on moths while walking across the tundra in loose groups of up to 40 individuals. Large numbers of ravens continued to frequent the area after the migration of Army Cutworms had passed; by mid-July there was an increasing abundance of grasshoppers and other insects at the pass (Hendricks 1993) and ravens may have switched their diet to include these taxa.

The timing and nature of the migratory movement across the Beartooth Plateau was consistent with previous observations at lower elevations and high-elevation aggregation sites. Migration occurred in early July when adults typically disappear from prairie sites in Montana and Wyoming (Cook 1927; Pepper 1932; Pruess 1967). Grizzly Bear activity at nearby high-elevation moth aggregation sites begins to increase in mid-July (Mattson et al. 1991), just after the time of the migratory passage noted. Adult Army Cutworms tend to be most active at night (e.g., Pepper 1932), although Pruess (1967) noted that diurnal activity is sometimes reported at high elevations in southern Wyoming, as was the case on the Beartooth Plateau. Orientation of early summer migrations to the southwest has been noted previously in Montana (Pepper 1932), but feeding during migration has not been reported, to the best of my knowledge.

Large diurnal migrations of moths were not detected at Beartooth Pass during July in 1983, 1984, 1987 and 1988, indicating that the annual migration of adult Army Cutworms does not follow a fixed route to their summer aggregation sites in the Absaroka Mountains. Even if migration sometimes occurred at night, moths would have been detected, because migrations apparently last several days and many individuals would have flushed from tundra vegetation during my morning traverses of the site. This did not occur during the other four summers of my residency at Beartooth Pass. Gross fluctuations in moth populations could also account for failure to detect migrations during those four summers, especially if years of apparent absence corresponded to years of low moth population size. Large fluctuations in moth populations did not appear to occur at nearby aggregation sites in the Absaroka Mountains during 1987-1989. Frequency of Grizzly Bear scats containing Army Cutworms (Mattson et al. 1991) ranged from 64.0-92.1% (ingested volume of moths ranged from 66.6-92.1%); the years of lowest and greatest moth presence in bear scats were 1987 and 1988, respectively, during which I did not detect movements of moths at Beartooth Pass. The Beartooth Plateau is crossed with some degree of regularity, however, as Pattie and Verbeek (1966)

probably witnessed a similar Army Cutworm migration at Beartooth Pass on 11 July 1963, when they reported 13 ravens feeding on large numbers of moths. Much remains to be learned of the migration of Army Cutworms, but their movement through any high-elevation site probably depends on temporary local weather patterns and the source of the migratory populations on the plains, both of which can vary from year to year (Pruess 1967, personal observation).

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News and Comment

Notices

Addendum: The length of Pleistocene interglacials

In the last issue of *The Canadian Field-Naturalist* 111(4): 696-697, I reviewed the book *Pleistocene Amphibians and Reptiles in North America* by J. Alan Holman and pointed out that the previous interglacial, the Sangamonian, was estimated to have lasted in the order of 10 000 years, and that a similar length of time had now elapsed since the Wisconsin. However, in a recent paper, "Duration and structure of the past four interglaciations" by Isaac J. Winograd, Jurate M. Landwehr, Kenneth R. Ludwig, Tyler B. Coplen, and Alan C. Riggs in *Quaternary Research* 48: 141-154

(1997) the authors present new evidence to back a conclusion that each of the last four interglacials lasted between approximately 20 000 to 26 000 years, rather than the more generally accepted 11 000 to 13 000 years. However, periods of relative climatic plateaus in an interglacial are in the order of 15 000 years to 10 000 years and a model based on this information matched to our current knowledge leads them to predict that Holocene-(the present)-like temperatures could last as long as another 5000 years or begin to cool as early the next millennium.

Field Botanists of Ontario Newsletter: Potential Ontario Plant Additions

The *Field Botanists of Ontario Newsletter* Volume 10(2) contains a feature of special interest to many Ontario naturalists: "Potential Additions to the Native Flora of Ontario" by Michael J. Oldham is an annotated compilation listing 100 vascular plant species that are native to areas near Ontario but not yet recorded for the province. Brief notes on nearest records, habitat, and recognition are included. As new species for Ontario are still being reported, even in recent years, despite the amount of previous botanical activity in the province, this list will help focus searches for further additions and help in alerting to the possible presence of species easily over-

looked or confused with similar species. Individual copies of this paper can be obtained from Michael J. Oldham, Herpetologist/Botanist, National Heritage Information Centre, Ontario Ministry of Natural Resources, P. O. Box 7000, 2nd Floor, North Tower, 300 Water Street, Peterborough, Ontario K9J 8M5. e-mail <oldhammi@epo.gov.on.ca> Membership in the Field Botanists of Ontario is currently \$12.00 per year including subscription to the *Field Botanists of Ontario Newsletter*. Further information can be obtained from W. D. McIlveen, Membership Chairman, Field Botanists Ontario, R.R.#1, Acton, Ontario L7J 2L7.

Froglog: Newsletter of the Declining Amphibian Populations Task Force (DAPTF)

Number 23, August 1997, contains: "Golden Toads, Null Models, and Climate Change" by J. Alan Pounds; "Frog Tea?"; "Using Local People to Monitor Frog Populations in Papua New Guinea"; "Commercial Trade in Australian Native Fauna; Review: The Action Plan for Australian Frogs"; and sections on DAPTF Merchandise; Froglog Shorts; Publications of Interest.

Number 24, November 1997, contains a report on DAPTF presentations at The Third World Congress at Prague (by Tim Haliday) in August, which included one by Stan Orchard on Canada, and, among six speakers on specific causes of amphibian declines, Christine Bishop (Canadian Wildlife Service) on

chemical contaminants. A resolution commending the efforts the DAPTF was passed by the Congress. Also in this number are "Report from Amazonia" by William E. Magnusson and "Amphibian Abnormalities: A Review" by Jamie K. Reaser and Pieter T. Johnson, and sections titled Froglog Shorts and Publications of Interest.

Froglog is available from Editor John W. Wilkinson, Department of Biology, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail daptf@open.ac.uk and on the World Wide Web at the following URL: <http://acs-info.open.ac.uk/info/newsletters/FROGLOG.html>

Recovery of Nationally Endangered Wildlife: *RENEW Report Number 7 1996/97*

This 24-page information-packed release is a promotion of the Committee on the **RE**covery of Nationally Endangered Wildlife, effectively written and designed by West Hawk Communications and coordinated by the Canadian Wildlife Service. The seventh number leads off with an explanation, What is RENEW?, and a Message from the Chair by the latter, Steven Curtis, Associate Director General, Canadian Wildlife Service. An Executive Summary follows, and a Cross-Canada Check-up gives progress updates on 43 of the 276 species designated by the companion, though independent, Committee on the Status of Endangered Wildlife in Canada (COSEWIC), by March 1997. The 1996 list of all species designated at risk in Canada by COSEWIC is included as a two-page table. Funding for Species gives a bar-graph of amounts spent on 28 individual species, ranging from \$853,400 for the Marbled Murrelet to \$1,000 for the Pygmy Horned Lizard, and includes an inset pie diagram of sources showing that of \$3,717,700 spent to recover RENEW species in 1996/97, \$2,115 (57%) was contributed by government agencies. Funding By Donors 1996/97 lists 90 participating institutions, agencies, societies and companies with both their person-year and dollar contributions, plus the lumped total for "private donations". Personnel (with affiliation) for RENEW Recovery Teams are listed for 33 "species" (using the COSEWIC terminology where a "species" is a collective population

unit defined as (page 12, bottom) "an indigenous species, variety or geographically defined population of wild fauna and flora", much the same definition as now commonly adopted by many molecular biologists and some others) and one ecosystem (the Okanagan, with 4 species at risk). For one "species", the eastern population of the Cougar, there is a notation "team on hold pending confirmation of existence of species"; while for Baird's Sparrow and the Ferruginous Hawk, it is explained "team unofficially disbanded", for the sparrow "due to species being delisted", and for the hawk "due to species downlisting to vulnerable". For Blanchard's Cricket Frog there is the comment "new team to be named to implement plan". Five additional species are listed without teams, three (Northern Bobwhite, Pacific Water Shrew, Townsend's Mole) because teams have yet to be named, one (Grizzly Bear) because "action deferred pending COSEWIC review" and one (Greater Prairie Chicken because "recovery deemed unfeasible, team disbanded 1994". There is a concluding table on the Status of Recovery Plans, species by species, for 41 forms, a list of federal and provincial agencies to be contacted for more information, and a list of RENEW member agencies or groups for 1996/97. Copies of RENEW Report #7 are available from RENEW, Canadian Wildlife Service, c/o Sylvia Normand, Environment Canada, Ottawa. Ontario K1A 0H3 Canada * e-mail: snormand@ec.gc.ca

Southeastern Canadian Studies on Species Richness and pH

Canadian Technical Report of Fisheries and Aquatic Sciences Number 2179: *Species richness and species occurrence of five taxonomic groups in relation to pH and other lake characteristics in southeastern Canada* by S. E. Doka, M. L. Mallory, D. K. McNicol, and C. K. Minns, 57 pages, 1997 (ISSN 0706-6457). is a collaboration between staff at the Great Lakes Laboratory for Fisheries and Aquatic Sciences, Department of Fisheries and Oceans, 867 Lakeshore Road, P.O. Box 5050, Burlington, Ontario L7R 4A6, Canada (Doka, Minns) and at the Canadian Wildlife Service, Environment Canada, Ontario Region, 49 Camelot

Drive, Nepean, Ontario K1A 0H3, Canada (Mallory, McNicol). The report's purpose is to summarize the data compiled and analyses used in preparing new predictive models to relate lake characteristics (chemistry and physical features) to the occurrence of selected biota (zooplankton, macroinvertebrates, fish, amphibians and waterfowl) as part of the *Aquatic Effects Part of the Long-Range Transport and Acid Deposition Assessment Report* (edited by Dean Jeffries). Copies of Report Number 2179 are available from McNicol (CWS) or Minns (FAO) at the above addresses. Don McNicol can also be reached by e-mail: Don.McNicol@ec.gc.ca

Abstracts from 1997 Canadian Amphibian and Reptile Meetings

The program and abstracts for the combined meeting of the Canadian Amphibian and Reptile Conservation Network (2nd Annual Meeting), the Task Force on Declining Amphibian Populations in Canada (7th Annual Meeting), and the Canadian Association of Herpetologists [who give no indication that they keep track of how many times they have met] held at Acacia University, Wolfville, Nova Scotia, October 3-6, 1997 co-sponsored by the

Environment Canada, Canadian Wildlife Service - Atlantic Region, Endangered Species Program, contains abstracts of 51 presentations and the title/presenter only of one other. Copies are available from Stan A. Orchard, Canadian Amphibian and Reptile Conservation Network, 1745 Bank Street, Victoria, British Columbia V8R 4V6, Canada * Telephone/Fax: 250-575-7556 * e-mail: sorchard@islandnet.com.

1998 Meetings of Ichthyologists and Herpetologists in Canada

The 1998 Annual Meetings of the American Society of Ichthyologists and Herpetologists together with the Society for the Study of Amphibians and Reptiles, the Herpetologists League, and the Canadian Association of Herpetologists, will be held at the University of Guelph, Guelph, Ontario, 16-22 July 1998. Details on registration, accommodation, programs, and instructions on submitting potential contributions can be obtained from Dr. James Bogart, University of Guelph, Guelph, Ontario N1G 2W1. Department of Zoology Canada. e-mail: jbogart@uoguelph.ca.

The 1998 combined meeting of the Canadian Amphibian and Reptile Conservation Network (3rd Annual Meeting), and the Task Force on Declining Amphibian Populations in Canada (8th Annual Meeting) will be held in Saskatoon, Saskatchewan in October 1998. Details on registration and program may be obtained from Stan A. Orchard, Canadian Amphibian and Reptile Conservation Network, 1745 Bank Street, Victoria, British Columbia V8R 4V6, Canada * Telephone/Fax: 250-575-7556 * e-mail: sorchard@islandnet.com.

Alberta Wildlife Status Reports

The Wildlife Management Division of the Alberta Natural Resources Service reviews the status of wildlife species in Alberta every five years. In 1991 and 1996 it assigned individual species to "color" lists which reflect perceived level of risk to populations which occur in the province. The Alberta Wildlife Status Report Series gives priority to species judged potentially at risk (Red or Blue listed), those that are of uncertain status, or those considered at risk at a national level by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). The series is published by the Alberta Wildlife Management Division and the Alberta Conservation Association.

The reports currently available are:

1. Status of the Piping Plover (*Charadrius melodus*) in Alberta, by David R. C. Prescott. 19 pages.
2. Status of the Wolverine (*Gulo gulo*) in Alberta, by Stephen Peterson. 17 pages.
3. Status of the Northern Long-eared Bat (*Myotis septentrionalis*) in Alberta, by M. Crolina Caceres and M. J. Pybus. 19 pages.

4. Status of the Ord's Kangaroo Rat (*Dipodomys ordii*) in Alberta, by David L. Gummer. 16 pages.
5. Status of the Eastern Short-horned Lizard (*Phrynosoma douglassii brevirostre*) in Alberta, by Janice D. James, Anthony P. Russell, and G. Lawrence Powell. 20 pages.
6. Status of the Prairie Rattlesnake (*Crotalis viridis viridis*) in Alberta, by Sheri M. Watson and Anthony P. Russell. 26 pages.
7. Status of the Swift Fox (*Vulpes velox*) in Alberta, by Susan E. Cotterill. 17 pages.
8. Status of the Peregrine Falcon (*Falco peregrinus anatum*) in Alberta, by Petra Rowell and David P. Stepnisky. 23 pages.
9. Status of the Northern Leopard Frog (*Rana pipiens*) in Alberta, by Greg Wagner. 46 pages.
10. Status of the Sprague's Pipit (*Anthus spragueii*) in Alberta, by David R. C. Prescott. 14 pages.
11. Status of the Burrowing Owl (*Speotyto cunicularia hypugaea*) in Alberta, by Troy I. Wellicome. 21 pages.

For copies contact: Wildlife Management Division, 4th Floor, 9945 108th Street, Edmonton, Alberta T5K 2M4, Canada.

FRANCIS R. COOK

Book Reviews

ZOOLOGY

Amphibians & Reptiles Native to Minnesota

By Barney Oldfield and John J. Moriarty. 1994. University of Minnesota Press, Minneapolis, Minnesota. 237 pages illus.

The classic work on the Reptiles and Amphibians of Minnesota appeared in 1944 from the same publisher and was authored by W. J. Breckenridge, who has penned the Forward to this book. That the present edition is entirely new is immediately evident by the glossy paper and colour photographs throughout. It is also apparent in the streamlined species accounts with designer-driven wide white text margins with state distribution maps and secondary photos inset in it, and page-wide feature photographs across it. The photographs are the strength of this book, superb, sharp, magnificent. The distribution maps, however, are disappointing. They perpetuate the tradition of its 50-year plus predecessor in presenting only one centred dot per county, losing the detail expected from a regional work despite the counties being many and small.

The 48 species accounts (5 salamanders, 14 frogs, 9 turtles, 3 lizards, 17 snakes) cover Description, Distribution, Habitat, Life History, and Remarks. All of the 19 amphibians and all but 5 of the 29 reptiles occur in Ontario, Manitoba or Saskatchewan, many in two or all three, so the book is very useful to Canadian naturalists. Key statements are referenced, but the text by veterinarian Oldfield and wildlife specialist Moriarty does lack the care and originality that marked Breckenridge's pioneering work, a text adapted from his Ph.D. thesis.

A few examples of inadequacies and confusion suffice to characterize the text. A photo on page 70 of the American Toad, *Bufo americanus*, labelled "albino" is of an individual which apparently lacks melanin but has other pigment and normally coloured eyes. *Bufo hemiophrys* is treated as a species despite admission (page 74) of an "intergradation zone in Manitoba and Ontario" with the American Toad. There is no mention made of the earlier documented hybridization where the two contact in the North and South Dakota and apparently no examination of the variation in Minnesota itself. In the same account (pages 73-74) it is stated "In Canada they are found on the prairies of Manitoba and Saskatchewan" without mention that it ranges to Alberta and the southern edge of the Northwest Territories. Immediately after, under habitat, it is stated that "Canadian Toads are found in the same habitats as American Toads, ranging from woodlands to wetlands. They are not found in the interior

of vast expanses of prairie" (this apparently is meant to apply only to the United States). In the description they note "The dominant spots are black, with one or two warts per spot" although the photo immediately above shows more warts in most such spots, as has been well documented in the literature (F. R. Cook. 1983. *An analysis of toads of the Bufo americanus group in a contact zone in central northern North America*. National Museums of Canada Publications in Natural Sciences 3: viii + 89 pages; a publication that the authors cite). A citation of D. M. Green's paper (1983. *Herpetologica* 39: 28-40) states (page 74) that he "treats them as separate species that sometimes hybridize when their ranges overlap" although Green actually showed with a limited electrophoretic analysis on one transect the same complete intergradation on contact that Cook had demonstrated from morphological analysis of larger samples and five transects. Interestingly, when a similar pattern of interbreeding occurs in chorus frogs (*Pseudacris*) the authors have opted to reject recent conclusions and maintain the forms as subspecies rather than separate species (pages 84-86) and justify this on the lack of Minnesota studies.

There is a brief history of herpetology in Minnesota to open the book, and sections on habitats (also, like the species accounts, with superb photographs), hints on observing, studying, and photographing, a discussion of conservation, common problems (snakes sheltering in your house, turtles nesting in the yard, etc.), a checklist and a key. The latter is especially innovative, with wheels of characters, leading from general in the centre to species defining at the periphery. These are attractive but some useful defining characters (such as the bar position on the hind legs of Green and Mink frogs) are omitted.

The book concludes with a discussion of species which might yet be found in the state, a glossary of terms, a section titled resources (key regional, North American, and general books, tapes of calls, photographic references, and organizations), and a literature cited.

Because nearly all the species covered also range into Canada, and the quality of the photographs, this book deserves a place on any eastern or central Canadian naturalist's bookshelf. As a primary reference source it must be used with caution and checking against other references is advised.

FRANCIS R. COOK

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A Monograph of the Colubrid Snakes of the Genus *Elaphe* Fitzinger

By Klaus-Dieter Schultz with contributions by Andre Entzeroth. 1996. Koeltz Scientific Books, CR 58001 Havlickuv Brod, Czech Republic. 439 pp., illus.

If it is true that the larger the snake the bigger its impression on the public, than this book should gain wide attention. It deals with some of the largest harmless snakes in the world that are not members of the two groups that have tropical giant constricting members, the boas and the pythons. The representatives of the family Colubridae grouped here as the genus *Elaphe*, also constrictors by habit, are collectively called rat snakes because rodents are a diet staple for most (although they also may frequently take birds, their eggs, and some other prey as well). Included species attain average lengths of 50 to 250 cm and are widely dispersed, occurring from southern Ontario to Costa Rica in the Americas and in Eurasia from Spain to Indonesia. *Elaphe* are absent from the southern continents: South America, Africa and Australia. They are widely kept as pets and in zoos around the world, and this coffee-table-sized book with its detailed species-by-species accounts, spot and shaded distribution maps, numerous black-and-white diagrams of scale and pattern characters, charts and diagrams, and 58 plates of up to 8 individual colour photographs is aimed to especially appeal to herpetoculturalists and researchers as a core reference.

Forty species are covered, 32 Old World and 8 New, including all the species long associated with the generic name. The authors do, however, refer to the chaos of the systematics of these snakes; various included species are sometimes placed in other genera and the biochemical evidence indicates that the

grouping is far from a "natural" one. For example, the distinct North American genus *Pituophis* is probably closer to the North American snakes included in *Elaphe* than the latter are to the Old World *Elaphe*. No attempt has been made to assess the whole genus since the late 1890s but the present effort, although titled a monograph, is not intended as a revision. It provides no new phylogenetic nor zoogeographic synthesis, although a listing of all fossil forms, the earliest from the Miocene, is included. It is, however, a monumental encyclopedic compilation of existing data, including examination of specimens in 16 major museums world-wide, only one of which was in North America (the United States National Museum).

Two species occur in Canada, both in Ontario: the Black Rat Snake, *Elaphe obsoleta*, and the Fox Snake, *Elaphe vulpina*. Canadians are recognized for important studies in the natural history of both; notably Patrick Weatherhead and his students Brent Charland and D. J. Hoysak, for the former, and Donald Rivard, who did his Master's thesis under the direction of D. A. Smith, on the latter, all out of Carleton University in Ottawa. Both species are restricted in distribution and in jeopardy in their Canadian ranges, although portions of their populations are in National Parks; St. Lawrence Islands for *E. obsoleta* and Point Pelee, Georgian Bay Islands and Bruce Peninsula for *E. vulpina*.

FRANCIS R. COOK

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Coloniality in the Cliff Swallow: The Effect of Group Size on Social Behavior

By Charles R. Brown and Mary Bomberger Brown. 1996. The University of Chicago Press, Chicago. xiii + 566 pp., illus. Cloth U.S. \$95; paper U.S. \$34.95.

I attended my first annual meeting of the Animal Behavior Society in 1984, in Cheney, Washington. Charles Brown was there too, and I was in the room when he gave the presentation that earned him the W. C. Allee Award for best student paper. His talk was on foraging behaviour and information transfer in Cliff Swallows. The quality of data and interpretation that marked that early work has obviously remained with the Browns throughout the many years of research they have since devoted to Cliff Swallows, as is evidenced by this excellent monograph.

Cliff Swallows breed in colonies of various sizes (from 2 to 3700 nests) underneath overhangs on cliffs, bridges, or culverts. The mud nests are acces-

sible, and the birds are relatively tolerant of people and manipulation. Cliff Swallows are abundant in the open terrain of Southwestern Nebraska, where the Browns have studied them. In this book, data from a 10-year period (1982-1991) are analysed in an attempt to answer two main questions. First, what are the advantages and disadvantages of living in colonies? The answers occupy separate chapters. The main disadvantages are increased levels of parasitism by swallow bugs, of predation by bull snakes, and of brood parasitism by conspecifics. The main advantages are reduced competition for nest sites, better annual survivorship, and a clear increase in foraging efficiency through information transfer at the colony site. Overall, this translates into a better annual reproductive success at colonies of intermediate size. (The jury is still out on lifetime reproductive success.) The second question is: why do colonies

vary in size? Here the answer is tentative: different phenotypes may require different optimal colony sizes. The authors identify this as a major topic for further study.

The book is long (482 pages of text) and many variables are treated (calendar date, colony size, nest position, nest age, parasite numbers, various behavioural and reproductive parameters, survival rates, etc.). This wealth of information seems bewildering at first, but the clear writing style, the logical internal organisation of the chapters (including summaries at the end), and the straightforward data interpretation kept me on track. The statistical analyses are simple: almost all of them are correlations, the rest being chi-square tests. I counted 36 photos, 126 figures (many with multiple panels), and 37 tables, all of them informative and well conceived.

The subject index is very complete (37 pages, and all the words I tested were there). The reference sec-

tion lists 912 entries, on swallow biology or the costs and benefits of living in groups. This great number of references can be attributed to the fact that each chapter begins with a 2-page mini-review of the topic being considered, often followed by a section on relevant aspects of the natural history of Cliff Swallows.

For those who are already familiar with the Browns' scientific papers and who may consider the book redundant, beware: the authors have added new data to the original analyses. The conclusions are sometimes altered, but, admittedly, not often and not to a great extent. Altogether, the Browns' body of work on swallows is remarkable, be it in the form of papers or in the form of this book.

STÉPHAN REEBES

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Reptiles and Amphibians of Prince Edward County, Ontario

By Peter Christie. 1997. Natural Heritage Books, Toronto, Ontario. Illus.

Prince Edward County is an irregular peninsula near the east end of Lake Ontario, west of Kingston, east of Toronto, and south of Ottawa, isolated from these major centres of biological investigation but far from inactive. In 1979, Jack Christie, Director of the Glenora Fisheries Station of the Ontario Ministry of Natural Resources, and Tom Huff, Director of the Reptile Breeding Foundation, Picton, both in the County, approached me for support in their bid for summer government funding available for student projects. Their success put naturalist Penny Briggs and seven university and high school students from the area (Moirra Allen, Fiona Burrows, Peggy S. Conley, Peter Christie, Jacqui Duyzer, Eric Holmberg and Shane Strenburgh) into the field from 14 May to 10 September that year. It was money well invested.

Over 300 original records from 190 sites were compiled, including weather and habitat details, on standard data sheets supplied by the herpetological unit of the National Museum of Canada (Natural Museum of Canada) [now Canadian Museum of Nature]. These were deposited and maintained there along with selected voucher specimens. Although outstandingly successful in the field, the project lacked funding to analyze and write up the data collected and produced only a typescript summary report.

Tom Huff left the Reptile Breeding Foundation in the early 1990s and it failed a few years after, the Canadian Museum of Nature abolished its research program in herpetology in 1993. Jack Christie died

in retirement early in 1997 and Tom Huff early in 1998. The student participants have long dispersed. But one, Jack's son Peter, has returned to Prince Edward County and brought the information together as part of a guide to Prince Edward County species and a useful model for similar efforts elsewhere.

Peter, who subsequently has been a journalist and editor with papers in Ontario (London and Kingston), Thailand and Japan, has opted for a straightforward format that is most effective. After an introductory section covering sources and organization, there is a brief description of Prince Edward County, species accounts, afterword, 12 references, and three appendices: a checklist of Prince Edward County species; the singing dates in the county for frogs; and a list of museum specimens for the county from six institutions.

The bulk of the book is the species accounts. Each has two sections: description (brief identifying features with remarks on preferred habitat from the literature) and distribution (county records and variation). The latter blends together several sources of information. First are the observations of the 1979 survey. These are augmented with subsequent records contributed to the Ontario Herpetofaunal Summary, and a 1930s survey conducted by the Royal Ontario Museum and written up by E. B. S. Logier in 1941 (*A Faunal Survey of Prince Edward County, Ontario*, University of Toronto Press). Occasional additions are from wetlands surveys conducted for the Ministry of Natural Resources, the Long Point Bird Observatory's Marsh Monitoring Program, observations at the Prince Edward Point National Wildlife Area made by Fiona Burrows (who had also partici-

pated in the 1979 survey), and the personal observations of Jack Christie and Tom Huff during their years of residence in the County. Included for each species is a spot distribution map giving Prince Edward County records and functional sketches aid visual identification. Tribute is justly made to Mike Oldham and the Ontario Herpetofaunal Summary for compilation of records from these diverse sources and making them available.

Five turtles, seven snakes, five salamanders, eight frogs (including one toad), a total of 25 species are documented. An additional five unconfirmed species (four snakes and one frog), based on reports unsubstantiated by voucher specimens, are also given accounts in a separate section. These are followed by mention of four whose status is purely hypothetical. All species are illustrated with black-and-white sketches of variable success by the author, best for frogs and poorest for the scaleless and somewhat bloated snakes.

The afterword pays tribute to the persistence of amphibians and reptiles despite habitat degradation, ignorance and neglect of consideration for their requirements, and outright persecution and exploitation. It also highlights the persistence of those interested in the local herpetofauna and the particular value of the Ontario Herpetofaunal Summary and its role in collating and preserving observations of lasting value.

This book is an unabashedly a debt repayment to a father "who, by turning stones and woodland logs, uncovered his gift of curiosity that all of us carry still". Jack would be proud of the result. It should also please all who contributed directly and indirectly both in 1979 or either long before/after this survey by making more accessible the records of their efforts.

FRANCIS R. COOK

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Orioles, Blackbirds, and their Kin: A Natural History

By Alexander F. Skutch. 1996. The University of Arizona Press, Tucson, Arizona. 312 pp., illus. Cloth U.S. \$50.; paper U.S. \$21.95.

A good review of this book appeared in the *Wilson Bulletin* in 1996 (Volume 108, page 809). In it, C. R. Blem notes: "Who says there are no more heroes to emulate? Mine easily could be Alexander F. Skutch. At [a] time when study of whole organisms is considered passé by some, Dr. Skutch has produced a masterful account of the natural history of a very important group — the blackbirds (and after his 90th birthday!)."

Until recently, the American "blackbirds" (bobolink, blackbirds, meadowlarks, orioles, and allies) comprised the family Icteridae, and one referred to the species in that family as Icterids. Now, these birds are in the subfamily Icterinae, of the larger family Emberizidae (including many other species). Skutch's book, as he notes in the preface, covers those members of the former family Icteridae. He adds: "'Icterid' is probably the most precise and convenient designation ... and will be used throughout this book."

This is a book which I intend to read leisurely, for enlightenment and enjoyment, not just to write a review, for I've long had an interest in this group of birds. And I've already learned that it's easy to read. Skutch has brought together a lot of information (there's a 5-page bibliography), but the text looks

and reads more like a novel than a scientific treatise. The author's interest in these birds and his excitement in studying them in the field as well as learning about them through the observations of others is clear on almost every page. Still, it is Dr. Skutch's familiarity with many of his subjects in their native habitat that allows him to write so authoritatively and pleasantly. Of the Great-tailed Grackle, he states: "I delighted to watch their graceful maneuvers while they hovered, soared, and posed with dangling legs above the treetops, reminding me of gulls playing above a windy seashore."

Behaviour and ecology, food habits, relationship with other species, appearance, and vocalizations are described with an almost effortless style. Thirty-three lively scratchboard illustrations and a colour cover by Dana Gardner depict nearly that number of species. This book will serve as a stimulus and guide to further work on this group of birds, some of which are little known. One chapter, "Some South American Icterids", covers several species "that await more prolonged or thorough studies." I'll probably never get to South America, but thanks to Dr. Skutch, this book allows me to learn about and enjoy some of the birds in that distant land where he has spent so many years.

ROBERT W. NERO

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Encyclopedia of Canadian Fishes

By Brian W. Coad. 1995. Canadian Museum of Nature, Ottawa and Canadian Sportfishing Productions Inc. 928 pp., illus. + 16 plates. \$100.

Despite a few shortcomings, Brian Coad has done a commendable job in synthesizing information on all Canada's 1150 marine and freshwater species of fishes into one book. This well-organized, updated account arranges taxa by common name and, in addition to species and subspecies accounts, there are accounts for 4 classes, 46 orders, 199 families, and approximately 60 other miscellaneous groups such as ray-finned fishes, teleosts, shiners, pickerels, and fur-bearing trout. In addition, there is a section on fish structures, a list of all 30 exotic species known to be introduced into Canada, a short bibliography of major Canadian references on fishes, a glossary, and an extensive cross reference of scientific and common names. All taxa which have accounts appear in bold when mentioned in other sections of the book. This useful feature makes it immediately obvious that there is more information on the subject.

Species accounts which vary from only a quarter of a page for the undescribed flabby whalefish to over two and a half pages for species such as the rainbow trout include scientific name, French name, and other common names. Common family name is given but it would have also been desirable to be able to see the more familiar scientific family name in each account.

Common and scientific names are primarily based on McAllister (1990) which includes names which differ in many instances from the widely accepted names given in Robins et al. (1991). For example, Acadian whitefish is used instead of Atlantic whitefish for *Coregonus huntsmani*, lake cisco instead of cisco or lake herring for *Coregonus artedii*, and gaspereau instead of alewife for *Alosa pseudoharengus*. The promotion of more than one standard is going to create confusion in many cases. For example, the common name given for *Synodus lucioceps* is the smallscale lizardfish. However, Robins et al. (1991) call this species the California lizardfish and the smallscale lizardfish is the common name for another species, *Synodus caribbaea*. It is unfortunate that this book, which relies so heavily on the common name, fails to follow the valiant efforts of the Committee on Names of Fishes which strives to achieve uniformity and avoid confusion in nomenclature of North American fishes. This Committee has formulated extensive criteria in the naming of fish. These criteria aren't always followed by McAllister (1990) and perpetuated in this book. For example, the name snoutlet crotcheeler for *Bathypterois dubius* violates the tenet of good taste (spiderfish or notch feelerfish would be preferable) and names such as shortplate will-o'-the-wisp, canopener smoothdram, and doormat parkinglightfish

are unnecessarily complex, easily misspelled, or downright silly.

Fortunately, problems created by selecting less known standard are mostly compensated for by an extensive cross reference of scientific and common names. This important section is an improvement on similar encyclopedias of fishes such as McClane (1974) and Wheeler (1975) which both lack such an index.

A short general description of distribution for each species does not incorporate new information on Ontario range provided in Mandrak and Crossman (1992). For example, the bluntnose minnow and blacknose dace are both now known from north of Lake Superior. A lengthy Characters section begins with the description of the unique (diagnostic) characters of each taxon and a comparison with one or more closely related forms. The section is useful if the choice has been narrowed down to two or very few closely related taxa.

Almost every species is illustrated with a 5-6 cm line drawing, half tone or, rarely, a black-and-white photograph. In addition, 128 species are illustrated in colour. The drawings and photographs come from a variety of sources and the quality varies. Species are usually shown in side views but many species are also illustrated in top, bottom, and front views as well. Some of the best illustrations in the book are from excellent line illustrations by D. R. Harriott found in Hart (1973). The awesome task of assembling 1150 illustrations inevitably results in some errors and poor illustrations. For example, the northern madtom is illustrated with the distal margin of the dorsal fin black, a characteristic of the brindled madtom. The figure for the finescale dace shows a specimen which has two lateral bands and a small mouth indicating it is either a northern redbelly dace or a northern redbelly X finescale dace hybrid.

The Biology section follows a consistent format and, depending on available information, varies in length from "Unknown" for flabby whalefish to more than a page for game fishes such as coho salmon and yellow walleye. The section can include information on habitat, temperature tolerance and preference, depths occupied, movement, food and feeding behaviour, predators, notes on comparative growth between males and females, life span, age at maturity, spawning behaviour, time of spawning, fecundity, egg size, sensitivity to factors such as water clarity and sedimentation, and notes on importance to man. Forty-two important game fishes (primarily freshwater) also have additional information of interest to anglers (best time of year and regions to fish and the tackle, equipment, and bait to use) compiled by H. Waszczuk and I. Labignan. Information on reproduction, if available, usually occupies a large percent of the biology section (e.g.,

common shiner 67%; creek chub 68%). The status and year assigned is included for taxa classified up to and including 1993 by the Committee on the Status of Endangered Wildlife in Canada.

Sources of information used in each account are acknowledged in a general way in the introduction and bibliography. It is apparent, for instance, that Coad has used much of the information on the freshwater fish fauna which is in Scott and Crossman (1973). But much information which has appeared subsequent to this synoptic work has been added. For example, there are accounts for 29 species and 14 subspecies or distinct stocks which have been discovered or recognized as separate taxa since the publication of Scott and Crossman (1973), representing a 14% increase in the number of Canadian freshwater forms.

I would recommend this updated reference to both scientific and lay audiences. The book binding is a good one which is fortunate because it will be frequently used by those who own it. The layout facilitates finding information quickly and its shortcomings are outweighed by its complete coverage of the Canadian fish fauna and by the wealth of information presented.

A Guide to Whale Watching in the Maritimes

By David Lawley. 1997. Nimbus Publishing Ltd., Halifax, Nova Scotia vi + 76 pp., illus.

Dave Lawley is a typical Cape Breton resident. He is laid back, friendly, patient and enthusiastic about his island. These human qualities come through in his new, handy pocket-sized book. It has the flavour of the Maritimes and the enjoyment there is to be gained in whale watching. It is a charming book that will provide a good start to would-be whale watchers. Written in a straight-forward narrative style it is suitable for anyone from 10 to 99 years of age.

It will provide all you need to know about where to go, what to expect, and how to see these impressive mammals. I was very pleased to see that Dave has included shore-watching locations as well as the more publicised boat tours. His descriptions of what you might see are realistic, not the overblown hype I have seen in some advertising. I too, have been on boat trips and not seen any whales and I have watched from shore at irritatingly distant and unidentifiable whales. Whales, unfortunately for us, are independent and do not always appear when we wish them to. Using David's book will surely increase your chance of success.

I was surprised at the long list of tour boats now operating. When I surveyed Nova Scotia in 1994 there were 10 active (plus three potential) tour operators. Dave now lists 24 tour boats, nearly two and a

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ERLING HOLM

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Contribution number 98 for the Centre for Biodiversity and Conservation Biology, Royal Ontario Museum, Toronto, Ontario.

half times as many. My assessment was that there was barely enough tourist activity to support the original ten. Despite the pressure from political circles to move boats and captains from fishing to tourism, I advised against that until the tourism level had risen significantly. I wonder how long many of these boats will operate?

This book describes the basic information you need to know to see and identify whales of the east coast of Canada. The descriptions are brief, clear and to the point. There is nothing in these vignettes that is not in many other books. Dave has simply sifted all the material related to Canada into one handy reference. His real contribution is the directional guidance he provides and his personal experiences. I found myself nodding in agreement as I read an experience that closely paralleled my own. The book is illustrated with pleasant sketches that add to the charm of the book, but are not of great help in identifying a dark mass in the water.

I hope people buy this book. It will make them enthusiastic to go whale watching and encourage more people to go to Nova Scotia. If this happens maybe all those boats will stay in business and more people will see a whale and become ardent fans.

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Demography of the Northern Spotted Owl

Edited by E. D. Forsman, S. DeStefano, M. Raphael, and R. J. Gutierrez. 1996. Studies in Avian Biology Number 17. Cooper Ornithological Society, Camarillo, California. vi + 122 pp., illus. U.S. \$20.00.

The Northern Spotted Owl (*Strix occidentalis caurina*) has been considered both a blessing and a curse, depending of course, on which faction — environmentalists or loggers — is pontificating. This book, a synthesis of eleven coordinated studies of Spotted Owl demography is a rather rigorous, highly scientific read, geared primarily to population biologists and other related specialists. The purpose of the project (conducted in Washington, Oregon and California) was to obtain and analyse empirical population data on the Spotted Owl. The specific questions to be addressed were (1) are Spotted Owl populations declining?, and (2) are there gaps in the distribution of owls resulting from human-caused factors? Ultimately, the data were to be used in the management of forests (particularly the critical old growth forests) that lay within the range of the Spotted Owl; however, recommendations for management were not made as that was the purpose of another work by J. W. Thomas, and others in 1993.

This study was very well-organized and the book reflects this. Three chapters deal with background to the study, including the general biology of the owl, a background of previous demographic studies and an in-depth chapter on both the field and analytical methods employed by the research teams. Throughout reading this book, one gets the feeling of a highly coordinated, rigorous effort.

Nine teams of researchers covered eleven study areas from periods of four to nine years. Fourteen study areas were originally set up to be surveyed. Ironically, the three that were not reported at the Fort Collins 1993 Workshop (upon which this book is based) were the three areas that were the responsibility of the timber industry to cover. Each of the nine teams that did report, did so systematically; i.e., each study is directly comparable to all of the others. Even though there is an introductory chapter dealing

with the methods, there is a summary within each of the nine reports. This allows individual teams to more completely describe their particular study area as well as summarize the details of their particular study. Results are consistently well presented and discussions are to the point.

The final two chapters wrap up this project. The first is a so-called meta-analysis of the data presented by the individual teams, while the second is a critical look at the biases of the study (of both the field and analytical methods), an attempt to model the population change, and recommendations for further monitoring. A meta-analysis is a statistical tool used to interpret the data of several, similarly designed studies. It is more powerful than the set of separate analyses because it compares the individual studies for common trends. In this particular case, the outcome of the meta-analysis allowed the research team to conclude that the population of Northern Spotted Owls was in fact declining, a conclusion not unanimously reached by all the individual teams in their own study areas. However, the data were not sufficient to detect if the current decline is part of a regular fluctuation in the population, a drop to stability, or a trend towards extinction. The study only lasted nine years, which is less than one generation length of Spotted Owls. Therefore, predicting the future of these birds is untenable. The authors propose several options for further monitoring to determine the nature of the trend.

The editors have included a two-page appendix of acronyms and symbols, an area that I referred to frequently while reading the book. Unfortunately, not all acronyms were included in the appendix, which was inconvenient at times. However, all were defined within the text itself, and this oversight is negligible in an otherwise comprehensive piece of work.

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Lone Star Dinosaurs

By Louis Jacobs. 1995. Texas A & M University Press. 160 pp., illus. U.S. \$27.95. Canadian distributor UBC Press, Vancouver \$39.95.

One should not lament the overflowing number of books on dinosaurs. Even if some of these are ill-conceived, badly written, or published just to cash in on the dino-craze, it does illustrate one thing. There is a need to feed the desire of the populace to know more. And since there is a willing ear to hear the sto-

ries of ages past, paleontologists have a duty to tell the stories in a unique, lively way. *Lone Star Dinosaurs* is one of the latest attempts by Louis Jacobs, director of the Shuler Museum of Paleontology in Texas. "Mak[ing] science exciting" is Jacob's aim.

Geared toward the general fan of dinosaurs, *Lone Star Dinosaurs*, as the name implies, focuses on the prehistoric biota within the political boundary of Texas; who found what, where; and the history of

Texas dinosaurs. The problem of framing such a study within political boundaries is that the boundaries did not exist in the Cretaceous or any other period. Some of the dinosaurs, like *T. rex*, *Triceratops*, and its kin *Torosaurus* are also found in abundance outside of Texas, as far away as Saskatchewan. The purpose of Jacob's outline, I assume, is to use the Mesozoic fauna and flora of Texas as an illustrative tool, not just about the diversity of fossil remains within that state, but also as an example of continental and global indicators of distribution and evolution during the Mesozoic. "Texas cannot brag that it sports all of the more than three hundred species of dinosaurs known in the world" but it does have "representatives of all the basic groups of dinosaurs" (pages 24-25).

For example, fragmentary remains of the popular Triassic dinosaur *Coelophysis* have been uncovered in Texas. But, it is in nearby New Mexico that the best, most complete skeletal remains have been excavated (to which Edwin Colbert has recently published an engaging story of in *The Little Dinosaurs of Ghost Ranch*, Columbia University Press, New York, 1995). Without fear, Jacobs steps across the state boundary and provides a detailed narrative of the New Mexico material and the interpretation of the taphonomy of the site and biology of the animal.

There is, no doubt, a rich, diverse dinosaurian

fauna from Texas: the large sauropod and carnosaur footprints from the Paluxy River, giant crocodiles, and almost equally large flying reptiles called pterosaurs. Yet, much of the pleasure in reading *Lone Star Dinosaurs* is the history associated with the collecting of the dinosaurs and their interpretations. For example, the author describes the contributions by Roland T. Bird, collector for Barnum Brown of the American Museum of Natural History in New York, and his tireless efforts to find and then collect the Paluxy River specimens in the 1930s, or the discovery of the first baby nodosaur, an armored Cretaceous dinosaur from Texas, by a twelve year old kid from the city. This is the information that makes the book worthwhile.

Though *Lone Star Dinosaurs* may not be as exotic as his earlier book, *Quest for the African Dinosaurs* (Villard Books, New York, 1993) it is a pleasurable read. However, no matter how the Texas story is intertwined with the global perspective of dinosaurian evolution, I cannot help but think that *Lone Star Dinosaurs* is more appropriate to be a companion guide for a museum gallery, and a good one at that, rather than a popular study.

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The Breeding Birds of Quebec: Atlas of the Breeding Birds of Southern Quebec

Edited by J. Gauthier, and Y. Aubrey. 1996. Association québécoise des groupes d'ornithologues, Province of Quebec Society for the Protection of Birds, Canadian Wildlife Service, Environment Canada, Québec Region, Montreal. (English or français). 1302 pp., illus. \$14.95.

Over ten years in the making, *The Breeding Birds of Quebec* is a monumental work that will occupy a prominent place in the bookshelf of any serious student of Canadian birds. The Atlas is the culmination of the efforts of hundreds of observers and exhaustive historical research by dozens more. During the five-year atlas period, 932 participants, largely volunteers, surveyed 10×10 kilometer squares, collecting a total of over 200 000 records. Due to the sheer size of the Province, the field effort was restricted to the area south of $50^{\circ}30'$ North, reaching north to Blanc Sablon, but has been supplemented by an extensive review of the literature.

This book is more than an Atlas. In addition to the core species accounts, it contains a history of ornithology in the province stretching back to the early days of European exploration, a bio-geography of Quebec, a lavishly photographed taxonomy of the Province's birds, and an analysis of avian biodiversity in Quebec. The bulk of the book provides detailed

treatments of each regularly occurring species. Those which breed only in the extreme northern reaches of the Province, exotics, and occasional nesters receive a more concise treatment. Each species account includes a map, statistical profile, and sections on habitat, behaviour, distribution, and history and trends. The book is amply illustrated with colour photographs of most species, line sketches, and black and white photographs of nests and habitats.

The species maps, which occupy about half a page each, are very well done. Major rivers and lakes are clearly marked, making it easy to situate individual records. Each record is indicated by means of a small square, black in the case of a confirmed breeder and ochre for lower confirmation levels. Most species are portrayed against an overlay illustrating relevant ecological variables. For example, the map for Short-eared Owl is set against an overlay of "open habitat on unconsolidated deposits" (e.g., fields). Other species maps include boundaries of 18 ecological regions, allowing one to correlate records against habitats. A particularly useful feature is a detailed template on the inside cover, which explains the layout of the book and provides explanatory notes for the maps and species profiles.

In my perusal of the atlas I found no significant errors, and most of the information presented in the maps and species profiles appears accurate — although one can always question decisions taken on individual records (e.g., there is one Pine Grosbeak that seems awfully far south!) As usual in atlases, certain species are under-represented (owls, rails and other cryptic species) and there are regional biases, most notably a heavy concentration of well-covered squares in the south. Occasionally there are statements which do not seem entirely accurate, for example, the text suggests that Grey Partridge and Eastern Towhee are expanding in the Ottawa Valley when in fact they have both undergone dramatic reductions there over the past decade. However, these lapses do not reduce the overall high quality of the work.

The maps contained in this work are in and of themselves an invaluable contribution to our knowledge of the province's bird life and ecology. The objective of the remainder of the book is somewhat less clear. For example, most of the general informa-

tion provided on individual species is readily available elsewhere and tends to overwhelm the far more valuable analysis of the species in the Province. Moreover, while the section on taxonomy provides a showcase of some of the Province's many fine photographers, it might have been better marketed as a stand-alone coffee-table book.

Should you buy this book? At \$150.00 it is relatively expensive, and will be out of reach for some of its intended audience. In addition, its sheer bulk may put off some: at 1300 pages and seven kilos it is anything but a light read. Nonetheless, this book is a must for any person with a serious interest in the avifauna of the province, and no ornithological library in Canada will be complete without it. If you do not think that you cannot afford it, you can always check it out at your nearest library.

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BOTANY

Wetland Plants of Oregon & Washington

By B. Jennifer Guard. 1995. Lone Pine Publishing, Redmond, Washington and Vancouver, British Columbia. 239 pp., illus. U.S. \$19.95

This is a well written, nicely illustrated field guide that is packed full of information. The 155 plant species described in detail are illustrated with about 300 color photos and 74 line drawings. An additional 150 species are discussed to varying degrees, and sometimes illustrated to show features which distinguish them from similar species. The introduction gives a general idea of wetlands and how they function, the types of wetland communities, and an illustrated discussion shows the reader how to get the most out of the book. The "Keys to Identification," based on characters we see with the naked eye, occupy several pages.

The main section of the book, covering 188 pages, is divided into five chapters, each treating a different wetland community: Submerged and Floating Communities, Marshy Shore Communities, Wetland Prairie Communities, Shrub Swamp Communities, and Wooded Wetland Communities. Each community has its own logo and color tab in the upper corner of the page. Each chapter begins with an overview of the salient features of that community and a few habitat photos.

The book, in general, follows the one-page-one-species format common in many field guides. The page layout for each plant follows a standard pattern.

Thus making it easy to find comparable data on different plants. The lead banner, next to the logo for that community, contains one or more common names for the plant and the scientific (= Latin) name. The plant family, indicator status (following United States wetlands jurisdictions), and logos of communities where the plant also occurs are in a ancillary banner. The next headings for each description are Growth Habit, Leaves, Flowers, Fruits, Habitat, Natural History, and Similar Species.

For too long we have treated wetlands and waterways with great contempt due to an ignorance of their importance and makeup. Guides such as this definitely help in educating the public. Although some people cannot see the forest for the trees, I have had the problem in wetlands of not seeing the plants for the water. Part of my problem has been a perception that there is nothing but difficult-to-identify sedges and grasses. This book shows the great variety of plants in wetlands and, I'm sure, will make the identification of these plants easier and more enjoyable. Many of the plants in the guide are widespread in western North America. Thus the guide will be useful beyond the limits of Oregon and Washington.

Lone Pine Publishing has produced an aesthetically pleasing, easy to use guide. It is another success in their series of guides to the flora of the Northwest.

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Catkin-Bearing Plants of British Columbia

By T. Christopher Brayshaw. 1996. Royal British Columbia Museum, Victoria. vi + 213 pp., illus. \$24.95.

This useful field guide is a revised edition of a 1976 book. The distribution maps have been updated to 1989, a few new names are introduced and some species concepts have been revised.

The genera included are *Alnus*, *Betula*, *Castaneus*, *Corylus*, *Fagus*, *Juglans*, *Populus*, *Quercus*, and *Salix*. Sixty-nine taxa are given principal status, including five hybrids and two taxa which occur close to but not (yet) found in British Columbia. Many subspecies, varieties and forms are distinguished, either in the discussions or keys, and a few are illustrated. Most descriptions follow a standard format with emphasis on the characteristics of the habit, leaves, catkins, habitat, and geographic distribution. The black-and-white figures show details of branches, leaves, catkins, flowers, and capsules. The distribution maps are grouped in the back of the book.

Catkins are transitory; some form in late winter and are shed, in most species, in early summer. Considerably more emphasis on the off-season problem of distinguishing plants that have shed catkins from those woody shrubs and leafy trees that never produce catkins, and on catkin phenology would have been useful.

The order of the descriptions in the book, beginning with *Populus* and ending with *Quercus*, may perplex some readers; it follows the arrangement of

the family names in *Gray's Manual of Botany*. The inconsistent organization of the taxa within each genus may initially confuse users. For example, under the genus *Populus* the key includes six species and I expected to find all six described following the key, but only two are. However, the hybrid *P. × brayshawii*, a taxon not in the key, is described. The descriptions of the other four species in the key are, before the key, in the introductory paragraphs under the heading *Populus*. Further the treatment of hybrids varies. *Populus × brayshawii* a hybrid of *P. balsamifera*, is treated at the end of the section on that genus, whereas within the Willows the description of the hybrid *Salix × rubens* is inserted after *S. alba*, which is one of its parents.

The Index is annoyingly incomplete because it does not cite all occurrences of a name or topic. One example is the name *Betula pumila* which is on pages 142, 144, 148 and 201, but the Index cites only page 146, where the name does not occur. And none of the many subspecific categories are in the Index, although they occupy a significant portion of the book.

The guide contains a lot of detailed information and it will be very helpful in ecological and botanical surveys.

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Plants of the Kingston Region

By A. Crowder, K. E. J. Topping, and J. C. Topping. 1996. Queen's University, Department of Biology, Kingston, Ontario. 123 pp. \$14.00.

In 1970 Roland Beschel and colleagues published a checklist of the Kingston Region in southeastern Ontario. The present checklist covers the same area including islands in the St. Lawrence River, but excludes northern New York State. It includes parts of eight counties and all or parts of 70 townships and the Mohawk Nation land and extends roughly from Brighton to Prescott in the south to Plevna and Smiths Falls in the North.

The first nine pages include a short introduction and comments on the study area, sources of information, introduced plants, references, abundance, habitats/biology, acknowledgements, a map depicting the counties and townships, a map showing the precambrian shield, rivers, lakes, place names used in the text and major roads, and a map depicting percentages of woodland cover. The balance of the book, with the exception of a bibliography and index of family, generic, and common names, is devoted to the plant list.

In the body of the text the order of families follows Morton and Venn's (1990) alphabetical series for fern and fern allies and Dalle Torre and Harms (1907) for the families of Spermatophyta, Monocotyledons, and Dicotyledons. Within the families, genera and species are in alphabetical sequence. Within each family there are five columns. Column 1 indicates that there is a specimen of a particular species preserved in the Queen's University Herbarium (QK) and if it is introduced, by an asterisk (*); column 2 gives the latin name with authority, and synonymy when considered necessary; column 3, a common name when available; column 4 provides information on habitat, areas within the region and abundance; and column 5 gives the Dalle Torre and Harms generic number.

This new pocketsize checklist is an excellent update and will be most useful in the field and when working with floras which cover this part of Ontario.

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A Guide to the Orchids of Bruce and Grey Counties, Ontario

By Bruce-Grey Plant Committee. [1997]. Owen Sound Field Naturalists, Owen Sound, Ontario. 106 pp. illus.

Bruce and Grey Counties in southwestern Ontario are well known for their botanical riches, especially their orchids and ferns. The Bruce Peninsula forming the northern extremity of the area is particularly favoured. Lying between Lake Huron and Georgian Bay, these two counties on the dolostone bedrocks of the Niagara Escarpment have an exceptional diversity of forests, wetlands and open areas.

The book begins with a 14-page Introduction containing a brief description of the counties and their botanical history, a statement on the need for conservation, several sections describing specific features of the orchid family, and a section on how to identify the orchids with a key.

The main body of the work is an annotated species list that devotes a full page to each of the 48 taxa treated. For each taxon, introductory paragraphs describe the orchid as it occurs in the two counties. Descriptions and measurements of plants, flowers, and capsules are then presented in point form, accompanied by simple line drawings of a flower and a plant. There are no distribution maps. Part way through the book is a signature on glossy paper containing 48 colour photographs by Donald R. Gunn, as well as tables of climatic data, flowering times, and nationally and provincially rare taxa.

For the most part, this guide provides a reasonable introduction to the orchids of Bruce and Grey Counties. Its chief weaknesses are its reliance on older secondary sources that do not reflect the taxonomic advances of the 1990s, the poor reproduction quality of some of Donald Gunn's photographs, and the lack of detailed descriptions of the diverse habitats that make this area so interesting. In the past decade, papers have appeared that contribute to a better understanding of the varieties of *Cypripedium*

calceolus (*C. parviflorum*), and the status of *Malaxis unifolia*, *Platanthera huronensis*, and *P. macrophylla* with respect to morphologically similar species. For instance, being a coauthor of a paper treating *P. macrophylla*, I was not happy to see repeated the same old, erroneous tales with regard to its alleged super-large leaf size (Goldie gave it the name *macrophylla* to distinguish it from *P. hookeri*, not *P. orbiculata*), the inaccurate continental distribution given and the lack of understanding of the characters that distinguish it from *P. orbiculata*. With regard to the colour reproduction of the photographs, a number suffer from unrealistic colour shifts to the red or yellow. Particularly unfortunate is the yellowish wash given the photograph labelled *Platanthera hyperborea* (which is actually an excellent view of *P. huronensis* as can be seen from the morphology of the column) because one of the characters separating the two species is the colour of the flowers, yellowish green for the former species and whitish green for the latter. A more accurate rendition of the photograph can be found in *The Flora of Manitoulin Island* (Morton and Venn 1984).

The authors deserve credit for seeing this work finally into print almost two decades after its inception as an Ontario Ministry of Natural Resources guide to the orchids of one provincial part. Nevertheless, I look forward to a revised edition that will bring the orchids of this fascinating region even more clearly into focus and with a cover that lies flat.

Reference

Morton, J. K. and J. M. Venn. 1984. The flora of Manitoulin Island. Second revised edition. University of Waterloo, Waterloo. 106 pp.

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Michigan Flora: A Guide to the Identification and Occurrence of the Native and Naturalized Seed-plants of the State. Part 3: Dicots (Pyrolaceae-Compositae)

By Edward G. Voss. 1996. Cranbrook Institute of Science Bulletin 61 and University of Michigan Herbarium, Ann Arbor. xix + 622 pp. illus. U.S. \$16.50.

With the publication of Part 3 (Dicots concluded) the *Flora of Michigan*, one of the best North American regional floras, is now complete. The completion of this 40-year project is made all the more impressive by the fact that Edward Voss was the sole author for each of the over 2500 species treatments.

Each *Flora of Michigan* volume covers the same taxa as the appropriate volume of *Britton & Brown's*

Illustrated Flora of the northeastern United States and adjacent Canada. This gives the sparsely illustrated *Flora of Michigan* the benefit of ready comparison to the numerous, excellent sketches in *Britton & Brown's illustrated Flora* (why reinvent the wheel, right?). A remarkable amount of information is packed into each of the concise species treatments. They typically offer ecological observations and helpful, often original identification tips as well as a discussion on distribution in the state and/or beyond. Voss frequently provides clarification or at

least an explanation for nomenclatural or taxonomic problems and regularly discusses variation within particular taxa in Michigan. His rich knowledge of the history of Michigan (and Great Lakes) botanical investigation is repeatedly drawn upon. He also delights in pointing out arcane information about these plants which I suspect he hopes will further arouse the curiosity and interest of readers. Did you know, for instance, that 90% of the world's supply of mint oil was once produced with 150 km of Kalamazoo, Michigan? (Of course not!).

It is clear from the text of *Flora of Michigan* that Edward Voss is, above all else, a skilled teacher. He offers tips on the *process* of identifying plants and conducting field botany in Michigan throughout Volume 3, most based on his own extensively field-based experience. He is clearly interested in enhancing the *skills* of the reader, not just their raw knowledge. We are told, for example, how to separate two similar *Lithospermum* taxa by "petting" them (page 122). Later (page 126), Voss provides sound advice on the use of keys (when in doubt, try both options). This is great stuff which will provide substantial encouragement to new students and old "students" alike.

A strong feature of *Flora of Michigan* is the literature references provided at the start of most genera. These typically include the most recent treatments of the group in question and/or literature particularly pertinent to Michigan. The coverage here is thorough, extending to regional publications far removed from

Michigan (e.g., a *Trail & Landscape* reference concerning *Conyza*). It is impressive to note, by the way, the frequent references to the valuable contributions of Canadian investigators to Great Lakes botany, particularly in regards to the study of weed species.

I have but two bones to pick with *Flora of Michigan*, Volume 3. Firstly, an index to the entire work, like that in *Britton & Brown's Illustrated Flora*, should have been included. Such an index would save readers considerable time and trouble. Secondly and more significantly, the information provided by the dot distribution maps for each species (an excellent feature in themselves) could have been substantially enhanced. With relatively little extra effort it should have been possible to note the county distribution of the infraspecific taxa mentioned in the text through the use of different symbols. Similarly, records based only on old specimens (50+ years?) could have been indicated separately by open circles in order to put such taxa into a better historical perspective.

At the end of the day, however, this will be — it may already be — a classic of regional floristic studies. All botanists in the Great Lakes region of North America should have all three volumes. As the complete set will be sent (postage paid) to anywhere in Canada for the relatively modest price of U.S. \$51, the *Flora of Michigan* also constitutes an excellent value.

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Trees and Shrubs of British Columbia

By T. C. Brayshaw. 1996. University of British Columbia Press, Vancouver. 374 pp., illus. \$24.95.

Trees and Shrubs of British Columbia is the newest illustrated fieldguide in a long tradition of fieldguides on British Columbia trees and shrubs. This book is effectively the sixth edition of B. G. Griffith's *Guide to the Trees and Shrubs of British Columbia* which first appeared in 1934 as a mimeograph. As noted in the preface, Brayshaw has retained the form and content established by E. H. Garman in the second (1953), third (1963), and fourth (1970) editions, but made a number of significant changes to this book which include the addition of many previously unknown exotic and native species of woody plants to the province, updated taxonomy and nomenclature, revision and addition of a number of keys, and addition of a reference list and illustrations.

The introduction includes a brief discussion of what constitutes a shrub or tree, a section on classification and nomenclature, hybrids, and the manner in which the book is organized. The order in which the

plant families are presented throughout the book is Englerian and the system of classification used for the angiosperms follows that proposed by Cronquist (1979). A checklist of all of the plants included in this book follows the introduction, and is cross-referenced with the section of photographic plates. A series of easy-to-use diagnostic keys which break the trees of shrubs into families using leaves and reproductive structures are provided. In addition to providing keys that are based on the traditional approach of identifying plants using leaves and reproductive structures, Brayshaw provides a set of keys that are based only on vegetative characters. While their inclusion here may at first seem superfluous, their utility becomes significant when flowers and leaves are absent.

The bulk of the book is comprised of plant descriptions with the family being the fundamental unit of currency. The brief discussion following each family includes aspects of general architecture and diagnostic features (commonly reproductive) that all representatives of the family have in com-

mon, followed by a dichotomous key that separates the genera. This same format that was used to describe and sub-divide the family is used for each genus. Species descriptions include: a common and scientific name; a description of its appearance and habitat; diagnostic features of the leaves, fruits, and flowers; and line drawings and photographs. Although the line drawings are of good quality and illustrate the plant's general appearance and, often, one or more of the diagnostic characters, I found the photographs to be small and of poor quality. A discussion of the range and habitat is included with each species; however, distribution patterns and ecological requirements are often much more complex than indicated in the text. This problem has been noted by Brayshaw and an extensive list of ref-

erences dealing specifically with plant distribution patterns has been provided.

The terminology has been kept to a minimum and those terms deemed necessary have been included in an illustrated glossary. I found little wrong with this book and highly recommend it to anyone wanting a relatively inexpensive and easy-to-use fieldguide to the woody plants of British Columbia.

Reference

- Cronquist, A. 1979. How to know the seed plants. Wm. C. Brown Co., Dubuque, Iowa.

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The Alpine Flora of the Rocky Mountains Volume 1, The Middle Rockies

By Richard W. Scott. 1997. University of Utah Press, Salt Lake City. 901 pp., illus. U.S. \$110.

This flora of the Middle Rockies covers the mountainous areas which extend through most of Wyoming, and parts of southern Montana, eastern Idaho, northeastern Utah, and northwestern Colorado between latitudes 39°45'N to 45°37.5'N and longitudes 106°W to 112°W with a total map area of 325 134 km² (125 632 mi²). The mountain ranges found here are the Beartooth, Absaroka, Big Horn, Grose Ventre, Teton, Wind River, Hoback, Wyoming, Salt River, Medicine Bow, Wasatch, and Uinta.

The author had an early interest in mountains: their distributions, characteristics, environments, biota and in particular the alpine plants which "grow and thrive in a seemingly marginal and harsh environment". His work on the alpine plants of the Middle Rocky Mountains began with his M.S. thesis at the University of Wyoming which was entitled *The Alpine Flora of Northwestern Wyoming* and has expanded over many years to the present work.

The plants included in this flora are all that have been found or reported above the main timberlines in the region and is defined as "the upper limit of more or less continuous arborescent growth forms 3m or more in height". The author in the introduction describes the Alpine Zone under the following headings: Timberlines, The Alpine Landscape and Geomorphic Processes, The Alpine Environment, Adaptation of Alpine Plants, and The Alpine Zone. This is followed by a chapter entitled The Middle Rocky Mountains which includes descriptions of Geography, Drainage Basins, Formation of the Ranges, Glaciation, and the Mountain Ranges, all of which is most useful and interesting to one working

in the area and outside it. The flora is then described. It includes 51 families, 204 genera, 609 species, 55 subspecies and 251 varieties. This is followed by a key to the families.

The next 770 pages include family descriptions together with keys and descriptions for the genera and species plus habitats, the mountain ranges on which the species are found in the region, and the overall known distribution. Each species is accompanied with a distribution map and one or more illustrations on the same page. These illustrations have largely been borrowed from other recent publications with permission. The accepted latin names are all accompanied with the author's name, place and date of publication and are followed by the common name and in many instances an extensive list of synonymy.

This main text is followed by Appendix 1 (Glossary of Descriptive Alpine Terminology), Appendix 2 (Glossary of Botanical Terms), Appendix 3 (Authors of Accepted Species Names), Appendix 4 (Chromosome Numbers of Alpine Plants in the Middle Rocky Mountain Flora), a Bibliography, an Index of Common Names, and an Index of Latin Names.

This book will be invaluable for anyone studying the alpine flora of the middle rockies and nearby mountain regions and it will certainly be easier to work with than complete floras of the states in which these mountain ranges are found. With its weight of about 2½ kilograms (almost 4½ pounds), however, I would not recommend its use in the field or being carried in a packsack when climbing the mountains.

I did find a number of problems with this flora. First, the date of publication is January 1997. This date was confirmed with University of Utah Press

by telephone. The only dates provided, however, were the copyright date of 1995 and in the Library of Congress Cataloging-in-Publication Data date of 1996. A map of the western United States showing the area covered by this flora would have been most helpful for anyone consulting it from outside the region. Authors of other floras will not all agree with all the long lists of "synonyms". Measurements have been omitted from most species descriptions, because alpine plants "are dependent on and responsive to microclimates, and in many cases the sizes of parts and structures are a function of the habitat". I think that it would have been better to provide measurements of the species as they occur above treeline even though many also occur, and may be

somewhat larger, below treeline. What bothers me most, however, is the alphabetical lumping of all families of ferns, conifers, monocotyledons, and dicotyledons, particularly at a time when some families have changed their names or genera have been divided to form smaller families. It would at least have been better to maintain these four groups separately. No indication has been given as to the areas the other two volumes will cover or when their publication might be expected.

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Intermountain Flora: Vascular Plants of the Intermountain West, U.S.A., Volume Three, Part A, Subclass Rosidae (except Fabales)

By Arthur Cronquist, Noel H. Holmgren, and Patricia K. Holmgren. 1997. New York Botanical Garden, Bronx, New York. 446 pp., illus. Cloth U.S. \$75.00 plus postage and handling of \$4.50 + 6% of subtotal for non-U.S. orders or \$3.50 + 5% of subtotal for U.S. orders.

The Intermountain Region is the semi-desert region of the western United States between the Rocky Mountains on the east and the Sierra Nevada on the west. It is bounded on the north by the high mountains of Idaho and Oregon and on the south by the hot, desert, creosote bush of Arizona. Thus it includes all of the state of Utah, most of Nevada, and portions of Oregon, Idaho, Arizona, Wyoming, and California. Maps of this, with the floristic divisions and sections, are provided on the inside front and back covers and facing pages of this volume.

This is the sixth volume of the Intermountain Flora that has been published. Previous volumes were: I. Geological and botanical history of the region, its plant geography and a glossary and the vascular Cryptogams and Gymnosperms (1972); IIIB. Fabales which includes the families Mimosaceae, Caesalpiniaceae and Fabaceae (1989); IV. Asteridae, except Asteraceae, which includes 10 orders and 49 families in the area (1984); V. Asterales 1994; Monocotyledons (1977). All of these have been previously reviewed in *The Canadian Field-Naturalist*. Volume II which will include Magnoliidae, Hamamelidae, Caryophyllidae and Dilleniidae, together with a cumulative index for all the volumes is yet to be published. Hopefully this final volume will come in the near future.

This newest volume covering the Subclass Rosidae (except Fabales) treats 136 genera found in 40 families, the largest of which are the Rosaceae,

Onagraceae, Euphorbiaceae, and Apiaceae. Like the previous volumes, excellent keys, extremely detailed descriptions, synonymy with bibliographic references, and information on types, habitat, and distributional (both overall and within the Intermountain) information are provided. Again, in many cases these are followed by most interesting and useful comments, and where needed, the suggestion that further investigation of a particular entity or group should be undertaken. Again, species that occur in the Pacific Northwest as well as in the Intermountain region are illustrated by drawings created by Jeanne R. Janish and published in *Vascular Plants of the Pacific Northwest*. Other species are illustrated by new drawings. Because of the importance of illustrations this volume is dedicated to the primary illustrators, Bobbi Angell, Jeanne R. Janish, and Robin A. Jess.

Like in the earlier volumes, chromosome numbers are given, but again, unfortunately, there is no indication as to whether or not the counts were made on Intermountain material. In this volume 15 nomenclatural innovations have been made. A list of these has been provided on page 428.

This is another meticulous contribution to the knowledge of the Intermountain Region and will be welcomed not only by those working in the area and surrounding territories but also by botanists across North America and beyond.

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ENVIRONMENT

An African Savanna: Synthesis of the Nylsvley Study

By R. J. Scholes and B. H. Walker 1993. Cambridge University Press, Cambridge, U.K. xii + 306 pp., illus. U.S. \$69.95.

About 40 percent of Africa's land surface is classed as savanna. It stretches across the continent and extends north from South Africa to the edge of the Sahara Desert. It is home to an incredible variety of wild life and millions of people from many cultures. Despite the size and importance of "savanna ecosystems," they are understudied in comparison to many other large ecosystems found throughout the world. And given the rapid and continuing change resulting from the combined impact of human and natural forces and factors now at work in Africa, this book is timely; it enhances our knowledge and understanding of the composition, structure, and function of one of the largest ecosystems on the continent. The book is based on the findings of numerous studies completed between 1974-1990 in the Nylsvley Nature Reserve in northeastern South Africa under the auspices of the South African Savanna Biome Project.

Section I contains five chapters that introduce and define the concept of "African savanna" and provide synoptic reviews of the people, climate, geology, landforms, soils, flora, and fauna in and around the Nature Reserve. To assist readers like me who traditionally have found "savanna" a somewhat fuzzy term, Chapter One explores elements of the concept for which there is general agreement and elements that remains controversial. For example, Scholes and Walker maintain there is agreement around the central definition of savanna as a "tropical mixed tree-grass community ... in which ecological processes, such as primary production, hydrology, and nutrient cycling are strongly influenced by both woody plants and grasses ..." but ongoing debate about the definition of boundaries of the smaller ecosystems characterized by different vegetation types and patterns within this large biome.

In Section II, Chapters 6-9 synthesize the results of work completed on water dynamics, nutrient flow, fire regimes, and herbivory patterns. This Section prepares the reader for increasingly integrated reviews on primary production and decomposition studies contained in Section III. Community and landscape pattern and changes are examined in Section IV, with emphasis on: community composition, structure, and dynamics; species distribution patterns, effects of disturbance, and seed banks; tree-grass interactions with emphasis on competition and coexistence; and plant-herbivore interactions with emphasis on defense mechanisms and browser feeding patterns and behaviour.

Section V, entitled "Lessons for Nylsvley" contains three chapters that provide an overview of savanna ecology (including savanna ecosystem structure and function, models, and future directions of research), management applications, and advice to organizations engaged in projects similar to Nylsvley.

The book is well organized. It begins with the results of basic, thematic studies, and progresses to more integrated syntheses of the knowledge in the context of ecosystem composition, structure, and function. Each chapter begins with a brief background statement about the topic and ends with a summary of the research highlights. Black-and-white illustrations and tables are used throughout the book and a bibliography is provided for readers who elect to pursue topics in greater detail. "An African Savanna" is quite readable and recommended to students, managers, and scientists.

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Field Guide to Ecosites of Southwestern Alberta

By J. H. Archibald, G. D. Klappstein and I. G. W. Corns. 1996. Canadian Forest Service, Northwest Region, Northern Forestry Centre, Edmonton, Alberta. Special Report Number 8. xiv + 523 pp., illus. + map. \$29.95; as binder \$34.95.

Field Guide to Ecosites of West-central Alberta

By J. D. Beckingham, I. G. W. Corns, and J. H. Archibald. 1996. Canadian Forest Service, Northwest Region, Northern Forestry Centre, Edmonton, Alberta. Special Report Number 9. xiv + 630 pp. + map. \$29.95; as binder \$34.95.

These volumes are the newest additions to the continuing series of ecological guides published by the Canadian Forest Service. Each book is subdivided into 15 sections which include an introduction,

description of the study area, classification approach, system overview, application of the classification system, fact sheets, ecosite and ecosite phase fact sheets, soil-type classification, interpretations, plant

recognition, cited literature, glossary, and a series of appendices. The authors have undertaken the formidable task of attempting to recognize and classify the complex mosaic of vegetational patterns and microhabitats occurring within the lower foothills, upper foothills, montane, and sub-alpine forest communities. The ecosite and ecosite phase sections comprise the bulk of these books and include a general description of each site and details on the successional relationships and trends under different physical conditions, moisture and nutrient regime, topographic position, slope, aspect, edaphic characteristics, and floristic composition. The data listed for each ecosite and ecosite phase are cross-referenced with other pertinent book sections, flow charts, and appendices. Although the terminology and manner in which the data are presented may seem a little overwhelming at first, these books are well written and the plants discussed in each section are well illustrated. The authors should be congratulated on the results so far obtained.

These volumes however, clearly reflect the micro-management style and mandate of Forestry Canada and are designed to point out the "limitations and opportunities" of each microhabitat within a larger forest ecosystem. That is, each microsite is considered to be a sustainable resource and its potential value seems to have been measured against an economic yardstick. Though the authors espouse that ecosystem classification systems such as this one will enable us to better understand ecosystem dynamics and function, their preoccupa-

tion with implementation of an ecosystem management strategy has left fundamental environmental questions unanswered. Problems which I was able to recognize were few, but annoying nonetheless. Given that these volumes are ecological guides, the failure to provide at least a brief description of the plants in the plant recognition section was puzzling. The absence of Latin binomials in many of the sections, ambiguous terms such as "poor/rich nutrient regime", and need to continuously cross-reference the data in the fact sheets with other book sections were particularly vexing.

While these volumes are bursting with information, they seem to be in a format that only the authors and those intimately associated with the development and use of this system of ecosite classification can fully appreciate. Attempting to understand how to quickly implement this system of classification was reminiscent of the frustrating exercise of learning new computer software using the often incomprehensible manuals provided by the manufacturer. It is my opinion that the time investment required to learn how to use these books will be long, even for individuals familiar with ecological concepts and terminology. Nonetheless, if you have a great deal of time on your hands these volumes are potentially valuable resources.

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British Columbia — A Natural History

By Richard Cannings and Sydney Cannings. 1996. Greystone Books, Vancouver and Toronto. x + 310 pp., illus. \$45.00.

A wonderful book! Well written and beautifully illustrated, it presents what could be dull, dusty facts in an imaginative, highly readable mode. Part of my enthusiasm may be due to my reading the book in early March, when, after months, the temperatures were still much below freezing and there was a metre of icy, unskiable snow everywhere. It was refreshing, if not inspirational, to gaze at the two-page spread of the Brittle Prickly-pear Cactus in full bloom or at the carpet of April flowering Arrow-leaved Balsamroot under huge Ponderosa Pines. I began to feel the heat and smell the flowers.

However, the book is a lot more than pretty pictures. The photos and drawings were selected to illustrate phenomena of nature (to tell a story, if you prefer), whether it is the Western Toad (an individual species) or Krummholz (a treeline community).

The landscape of British Columbia is remarkable and its uniqueness is due to its topography. The

mountains determine where the precipitation falls and how much there is. That determines what plants and animals live in specific regions. The influence of one item, whether it be the soil, the height of the mountains, the woodpeckers, or the snails, determines or effects the individuals or landscape around it. And this interrelatedness is what the book is all about.

The book has ten main chapters. One treats the geology and the other nine deal with particular communities, such as rainforest, marine, grasslands, etc. The main focus of each chapter is the interrelationships between the land and the organisms. A few of examples illustrate the point:

1) How do fungi effect the survival of the famous Spotted Owl? A variety of the larger fungi, especially truffles, are the main food for the Northern Flying Squirrel, which, in turn, is the main prey of the Spotted Owl. The complex becomes more involved when the relationship between the tree and the truffles, i.e., a mycorrhizal association, is interjected.

2) How do Sea Otters assure the survival of Giant Kelp beds? The relationship became evident after humans eradicated the Sea Otters from much of their range. After the Sea Otters were gone the Giant Kelp began to disappear, and when they went so did the community of plants and animals they sheltered. What had happened was the Sea Urchin population exploded in the absence of their main predator the Sea Otters. The Urchins were eating the stems and roots of the kelp, and the kelp forests were replaced by "urchin barrens."

These connections and interconnections are the basic core of natural history (the web of life). The authors detail an interesting selection of relationships occurring the various communities.

The Epilogue, while describing the devastation caused by man, is a rational plea for sustainable

management of the magnificent natural resources of British Columbia.

The formatting of the book is excellent, the binding is substantial but flexible enough so the book lies open to the any selected page. On a note of minor criticism, the compilers of the index missed some topics, such as Skunk Cabbage (page 143), Sunspots (page 206), Nuclear polyhedrosis virus (page 196). White Mountain Aves (page 173), and page 222 is missing from the entries for mushrooms and truffles.

Highly recommended to all naturalists! It is the type of book that high school seniors should read, because it would encourage some to get seriously interested in biology, and others to get out and see the glories of Canada.

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MISCELLANEOUS

Charles Darwin, *Voyaging*

By J. Browne. 1996. Princeton University Press, Princeton, New Jersey. xv + 605 pp., illus. U.S. \$18.95.

When will the Darwin industry end? It is very trying at times to count the number of biographies (in book form, never mind specific analysis in essay form of his life or influence) written on Charles Darwin within the last decade and a half. Many of these are a rehash of the same old stereotype: a reclusive thinker, terribly worried about removing the last veil between humanity and animality. One of the best, I thought, was Adrian Desmond and James Moore's 1991 thick tome *Darwin, the Life of a Tormented Evolutionist* (Time Warner Company). If anything, the copious note taking of Darwin and his community were exploited by Desmond and Moore in a style that was more novel-like than dry historical. So, it was with some hesitation that I picked up the most recent Darwin biography *Charles Darwin, Voyaging* by Janet Browne.

Granted, of the heavy thinkers in the last century, Darwin left behind much, from daily expenses, to various versions of his species work, to deeply personal flatulence. And there are few people who have had the opportunity to delve deeply into this material than Janet Browne. For a number of years she has edited the voluminous correspondence of Darwin and is also editor of the *British Journal of the History of Science*. Yet, *Voyaging* also develops like no other book the associated players in Darwin's life and times with brief microhistorical sketches which for the most part distract little from the flow of the text; though there are some brief sketches that beg for more information. For example, brief mention is made of the developing relations between Darwin, at a time when he was look-

ing for editors for his species work if he were to die prematurely, and Hugh Strickland, an up and coming naturalist. Strickland's "potential [as a scientist] was never fully realized; he was run over by a train in 1853 while searching a railway cutting for fossils" (page 451). Unfortunately, in searching Browne's citation we find an error in the reference preventing further inquiry.

Despite a few minor glitches *Voyaging* is detailed to the extreme, from family history, Darwin's upbringing, and schooling ("I was so sickened with lectures at Edinburgh that I did not even attend [Adam] Sedgwick's eloquent and interesting lecture. Had I done so I should probably have become a geologist earlier than I did" (page 138)), to the Beagle voyage and marriage. It wasn't too long after settling down at Downe that his colleagues realized that "If Darwin had become a barnacle during the previous years, he now turned his house into the Beagle: a self contained, self regulating scientific ship methodically ploughing onwards through the waves outside" (page 530). It was at Downe that his experiments were conceived and implemented, wish lists of collections and experiments sent to sympathetic colleagues, that the formulation, clarity, and estimated response to the *Origin of Species* was made.

After 543 pages of text it is here that *Voyaging* ends at the precipice of Darwin publishing his thesis. This is a suitable point for the reader to take a break but, more importantly, a notable point for Darwin. Because, when Darwin publishes his ideas, after years of cooking in his head, they become fair game for any pope and popper to pick clean with victorian tooth and claw. The promised companion volume by Browne will assuredly pick up where the first left off.

Browne's biographical project is, at this time, the most definitive review of Darwin and his time. It is generally reader-friendly yet indepth. For the more seriously inclined, this book will provide as much information as desired. Combined with the anticipated second volume, however, *Voyaging*

may appear a little daunting to those just stepping into the field of Darwinia, a field that never seems to end.

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Restless Energy: A Biography of William Rowan, 1891-1957

By Marianne Gosztonyi Ainley. 1993. Véhicule Press, Montreal, 368 pp., illus. \$19.95.

As Marianne Ainley tells us in her Introduction, "William Rowan has been considered a Renaissance man, a man of integrity, a famous biologist, a flamboyant showman, a challenging teacher, and often a nuisance. His work as a scientist has been highly regarded by biologists all over the world, and his experiments have been covered in numerous zoology textbooks ... His life was one of extremes and contradictions. He knew luxury and comfort in European mansions, but revelled in roughing it in the wilds of Alberta. ... [He] knew the exhilaration of successful scientific discovery."

This superb biography begins with his family and origins; Rowan was born in 1891 in Switzerland of an Irish father, a railway engineer, and a Danish mother. He came into the world with two teeth, causing the family doctor at his birth to predict that he would be a genius.

Young Billy and his five siblings lived in Switzerland until 1898, then in France until his father died of pneumonia in 1900, when Mrs. Rowan moved her family to Bedford, 80 km north of London. Billy was an outdoors boy, and a voracious reader, captivated by the writings of Ernest Thompson Seton. When he was fourteen, his interest was furthered by the talk Seton gave at Bedford school. Rowan immediately set his sights on Canada. As soon as he finished school at age 17, he moved to Alberta to be a ranch pupil on the spread of an Englishman recommended by friends. He fell in love with Canada. After a winter in England, he returned to live in Otterburn, Emerson and Winnipeg, Manitoba. Here he met A. G. Lawrence, who became a life-long friend and encouraged him to make a career of natural history.

Rowan enrolled in the honours zoology course at University College, London, in 1911; his studies were interrupted when the First World War triggered his enlistment in the Royal Scottish Regiment Volunteers on 1 September 1914. He was discharged from the Army on medical grounds just over one year later, and obtained his B.Sc. (Honours) in 1917. He taught biology in a school in Hampshire until 1919 when he was appointed Lecturer in Zoology at the University of Manitoba. Rowan was welcomed as Canada's first scientifically trained ornithologist.

In the summer of 1920, after less than a full academic year at Manitoba, Rowan was chosen as Chair

of the new Department of Zoology at the University of Alberta, Edmonton, but with the rank of Assistant Professor. He was to be underpaid throughout most of his career until retirement in 1956.

His new employer, University President H. S. Tory, advised Rowan to "lay off birds," concentrate on laboratory research into other aspects of zoology, and work towards a D.Sc. degree. Tory felt that fieldwork was not science. Contrary to Tory's wishes, Rowan spent his weekends in the field, and began ground-breaking experiments in his backyard. He exposed juncos to daily increments of artificial light in November and December; their gonads responded by growing larger than those in wild juncos that arrived in spring. His papers, published in *Nature* in 1925 and the *Proceedings of the Boston Society of Natural History* in 1926, "almost instantly changed the course of migration research and led to the establishment of the discipline of photobiology."

In 1925 Rowan began study of a new subspecies of breeding dowitcher brought to his attention by A. D. Henderson of Belvedere, Alberta; this new subspecies he described in *The Auk* as *Limnodromus griseus hendersoni* Rowan. He also wrote an important series of papers on North American shorebirds for *British Birds*. An artist of appreciable skill, he earned additional money for his family of five children by selling sketches and paintings.

For his graduate studies Rowan enrolled in University College in the summers of 1921, 1927 and 1928, wrote his thesis on photoperiodism: "Manipulation of the reproductive cycle: seasonal histological changes in the gonads," and obtained his D.Sc. degree. Even more important for his peace of mind, University President H. S. Tory resigned in 1928 to become head of the National Research Council (NRC) in Ottawa, and was succeeded in Edmonton by the more understanding Dr. R. C. Wallace.

Extensive and complicated experiments with photoperiodism in crows caused more complexities than expected. First, in 1929, Rowan released only 69 crows treated by photoperiodism and 14 controls. Twenty-eight of the 54 crows that left the vicinity of the aviaries were killed, quite a few of them heading northwest, a reverse migration as predicted. Some of the fourteen controls stayed around Edmonton, and some went in the normal southeast direction of fall migration, though a month or more late.

In 1931, for an even larger crow experiment, Rowan

had hoped to capture 1000 crows, but trapped only 400. Divided into experimental groups and controls, some received placental and some pituitary extract and two dozen were castrated. On 24 November, 262 crows were crated, ready for a flight to Medicine Hat for release. But the pilot became ill and the morning was too foggy for takeoff. Two days later substitute pilot Grant McConachie, later President of Canadian Pacific Airlines, made his first commercial flight with Rowan and the crows. By mid-afternoon they were freezing in their unheated plane and were running out of daylight, so had to land and release the crows at Hackett, only 160 km southeast of Edmonton, rather than at Medicine Hat as planned.

Although now in Ottawa, Dr. H. S. Tory remained influential and continued to thwart Rowan. Not surprisingly, grant applications to the NRC were rejected, and Tory seems to have been the one who prevented Rowan from getting a British Empire Fellowship to fund a sabbatical in England. Tory failed to appreciate Rowan's innovative ability to formulate hypotheses, then test them. The Carnegie Corporation Grant did fund his only sabbatical in 1937-1938. His chief accomplishments that year were a major review paper on photoperiodism in plants and animals, research into the effect of night illumination on starlings in London, and a tour of the major ornithological researchers in Europe including Konrad Lorenz and Niko Tinbergen.

Rowan had always been subject to periods of depression. He failed to publish the results of research done after his sabbatical. The last chapters of this book tend to depress the reader somewhat, too. But despite his personal and family problems, Rowan designed the five-cent Whooping Crane stamp for Canada Post in 1955, got Lloyd Keith interested in researching the ten-year cycle of hares and grouse at Rochester, Alberta, gave talks at numerous conferences, became interested in the problems of native Canadians, and attracted large and appreciative audiences with his talks on CBC radio.

I have three minor points of criticism. Ainley largely neglects his bird banding results (he banded 6725 Franklin's Gulls in 1926), fails to evaluate or index his breeding records of the Evening Grosbeak in Manitoba, the second but then thought to be the first on record, and omits mention of his elevation to Fellow of the American Ornithologists' Union in 1950.

Rowan was "an intuitive, creative and highly energetic scientist who favoured an interdisciplinary approach to research." This well-written, scholarly biography of an important ornithologist, based on Rowan's extensive papers, with detailed footnotes, belongs in every Canadian library of reasonable size.

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NEW TITLES

Zoology

Annotated keys to the genera of nearctic Chalcidoidea (Hymenoptera). 1997. Edited by G. A. P. Gibson, J. T. Huber, and J. B. Woolley. NRC No. 40392. National Research Council of Canada, Ottawa. \$64.95 in Canada; U.S. \$64.95 elsewhere.

The big cats and their fossil relatives: an illustrated guide to their evolution and natural history. 1997. By A. Turner. Columbia University Press, New York. xviii + 234 pp., illus. U.S. \$39.95.

Biogeography of the reptiles of South Asia. 1996. By I. Das. Kreiger, Melbourne, Florida. 112 pp., US \$27.50.

***Birdwatching guide to southern Spain.** 1997. By M. Palmer. Arlequin, Chelmsford England. 89 pp., illus. £8.95.

A catalog of Scolytidae and Platypodidae (Coleoptera), supplement 1 (1990-1994). 1997. By D. E. Bright and R. E. Skidmore. NRC No. 40699. National Research Council of Canada, Ottawa. \$45 in Canada; U.S. \$45 elsewhere.

†The catfish connection: ecology, migration, and conservation of Amazon predators. 1997. By R. Barthem and M. Goulding. Columbia University Press, New York. xvi + 144 pp., illus. U.S. \$45.

***The complete dinosaur.** 1997. Edited by J. O. Farlow and M. K. Brett-Surman. Indiana University Press, Bloomington. 752 pp., U.S. \$59.95.

The crocodilians: reminders of the age of dinosaurs. 1997. By P. J. Perry. Watts, Danbury, Connecticut. 64 pp., illus. U.S. \$15.75.

***The EBCC atlas of European breeding birds: their distribution and abundance.** 1997. By W. J. M. Hajemeir, and J. J. Blair. Poyser, Harcourt Brace, Sidcup, England. clxi + 903 pp., illus. £55.

The ecology of a symbiotic community, volume 1. population biology of the Japanese lizard *Takydromus takydromoides* (Schlegel) (Lacertidae), and volume 2: the component symbiotic community of the Japanese lizard *Takydromus takydromoides* (Schlegel) (Lacertidae). 1996. By S. R. Telford, Jr. Krieger, Melbourne, Florida. 140 pp., U.S. \$27.50 and 160 pp. U.S. \$36.50.

A guide to bird education resources: migratory birds of the Americas, an annotated bibliography. 1997. Edited by S. B. Laughlin and D. M. Pence. American Birding Association, Colorado Springs. 148 pp. U.S. \$9.95 + U.S. \$3.75 shipping.

***The hummingbirds of North America.** 1997. By P. A. Johnsgard. 2nd edition. Smithsonian Institution Press, Washington. xiii + 278 pp., illus. + 24 plates. U.S. \$45.

Kaleidoscopic tree boas: the genus *Corallus* of tropical America. 1996. By P. J. Stafford and R. W. Henderson. Kreiger, Melbourne, Florida. 120 pp., U.S. \$28.50.

†**Life of the flycatcher.** 1997. By A. F. Skutch. University Oklahoma Press, Norman. xiii + 162 pp., illus. U.S. \$40.

Lizards. 1996. By M. Rogner. Translated from 1992 and 1994 German editions. Kreiger, Melbourne, Florida. 2 volumes.

†**Monitoring bird populations: the Canadian experience.** 1997. Edited by E. H. Dunn, M. D. Cadman, and J. B. Falls. Occasional Paper Number 95. Canadian Wildlife Service, Ottawa. 62 pp., illus.

Natural history of monitor lizards. 1996. By H. F. Delisle. Kreiger, Melbourne, Florida. 240 pp. U.S. \$48.50.

†**Neotropical rain forest mammals: a field guide.** 1997. By L. H. Emmons. 2nd edition. University of Chicago Press, Chicago. xvi + 307 pp., illus. + plates. Cloth U.S. \$80; paper U.S. \$25.95.

†**North America owls: biology and natural history.** 1997. By P. J. Johnsgard. Smithsonian Institution Press, Washington. 295 pp., illus. + plates. U.S. \$24.95.

***The origin and evolution of birds.** 1996. By A. Feduccia. Yale University Press, New Haven. x + 420 pp., illus. U.S. \$55.

***Patterns and processes of vertebrate evolution.** 1997. By R. L. Carroll. Cambridge University Press, New York. 448 pp., cloth U.S. \$85; paper U.S. \$39.95.

†**Rapport sur la situation de certaines populations indigènes de bar rayé (*Morone saxatilis*) au Québec et au Canada.** 1996. Par S. Trépanier et J. A. Robitaille. Ministère de l'Environnement et de la Faune, Québec. xii + 67 pp., illus.

†**Rapport sur la situation de la buse à épaulettes (*Buteo lineatus*) au Québec.** 1997. Par F. Morneau et A. Dionne. Ministère de l'Environnement et de la Faune, Québec. xiii + 73 pp., illus.

†**Rapport sur la situation de l'aloë savoureuse (*Aloa sapidissima* Wilson) au Québec.** 1997. Par J. A. Robitaille. Ministère de l'Environnement et de la Faune, Québec. xii + 93., illus.

†**Rapport sur la situation de la rainette faux-grillon de l'ouest (*Pseudacris triseriata*) au Québec.** 1996. Par J. Bonin et P. Galois. Ministère de l'Environnement et de la Faune, Québec. 39 pp., illus.

†**Rapport sur la situation de la tortue-molle à épines (*Apalone spinifer*) au Québec.** 1997. Par J. Bonin. Ministère de l'Environnement et de la Faune, Québec. viii + 62 pp., illus.

†**Rapport sur la situation du brochet d'Amérique (*Esox americanus americanus*) au Québec.** 1997. Par S. Lachance. Ministère de l'Environnement et de la Faune, Québec. xi + 54 pp., illus.

†**Rapport sur la situation du caribou (*Rangifer tarandus caribou*) du parc de conservation de la Gaspésie.** 1996. Par F. Boileau. Ministère de l'Environnement et de la Faune, Québec. ix + 49 pp., illus.

†**Rapport sur la situation du carajou (*Gulo gulo*) au Québec.** 1996. Par M. Moisan. Ministère de l'Environnement et de la Faune, Québec. 58 pp.

†**Rapport sur la situation du Faucon pèlerin (*Falco peregrinus*) au Québec.** 1997 par D. Bird. Ministère de l'Environnement et de la Faune, Québec. xiii + 76 pp., illus.

†**Rapport sur la situation du pygargue à tête blanche (*Haliaeetus leucocephalus*) au Québec.** 1996. Par S. Lessard. Ministère de l'Environnement et de la Faune, Québec. ix + 73 pp., illus.

***Reptiles and amphibians of Prince Edward County, Ontario.** 1997. By P. Christie. Natural Heritage/Natural History. 143 pp., illus. \$12.95.

The secret lives of birds. 1997. By P. Gringras. Firefly Books, Buffalo. 176 pp., illus. U.S. \$17.95.

Sea Cucumbers of British Columbia, Puget Sound, and southeastern Alaska. 1997. By P. Lambert. Royal British Columbia Museum, Victoria. 192 pp., illus. \$24.95.

Sex, color, and mate choice in guppies. 1997. By A. E. Houde. Princeton University Press, Princeton. 210 pp. Cloth U.S. \$49.50; paper U.S. \$19.95.

Shrikes: a guide to the shrikes of the World. 1997. By N. Lefranc. Yale University Press, New Haven. 192 pp., illus. U.S. \$35.

†**Situation du suceur cuivré (*Moxostoma hubbsi*) au Québec: espèce susceptible d'être désignée menacée ou vulnérable.** 1995. Par Comité d'intervention. Saint-Laurent Vision 2000. Ministère de l'Environnement et de la Faune, Québec. 42 pp.

†**So fruitful a fish: ecology, conservation, and aquaculture of the Amazon's tambaqui.** 1997. By C. Araujo-Lima and Goulding. Columbia University Press, New York. vii + 191 pp., illus. U.S. \$45.

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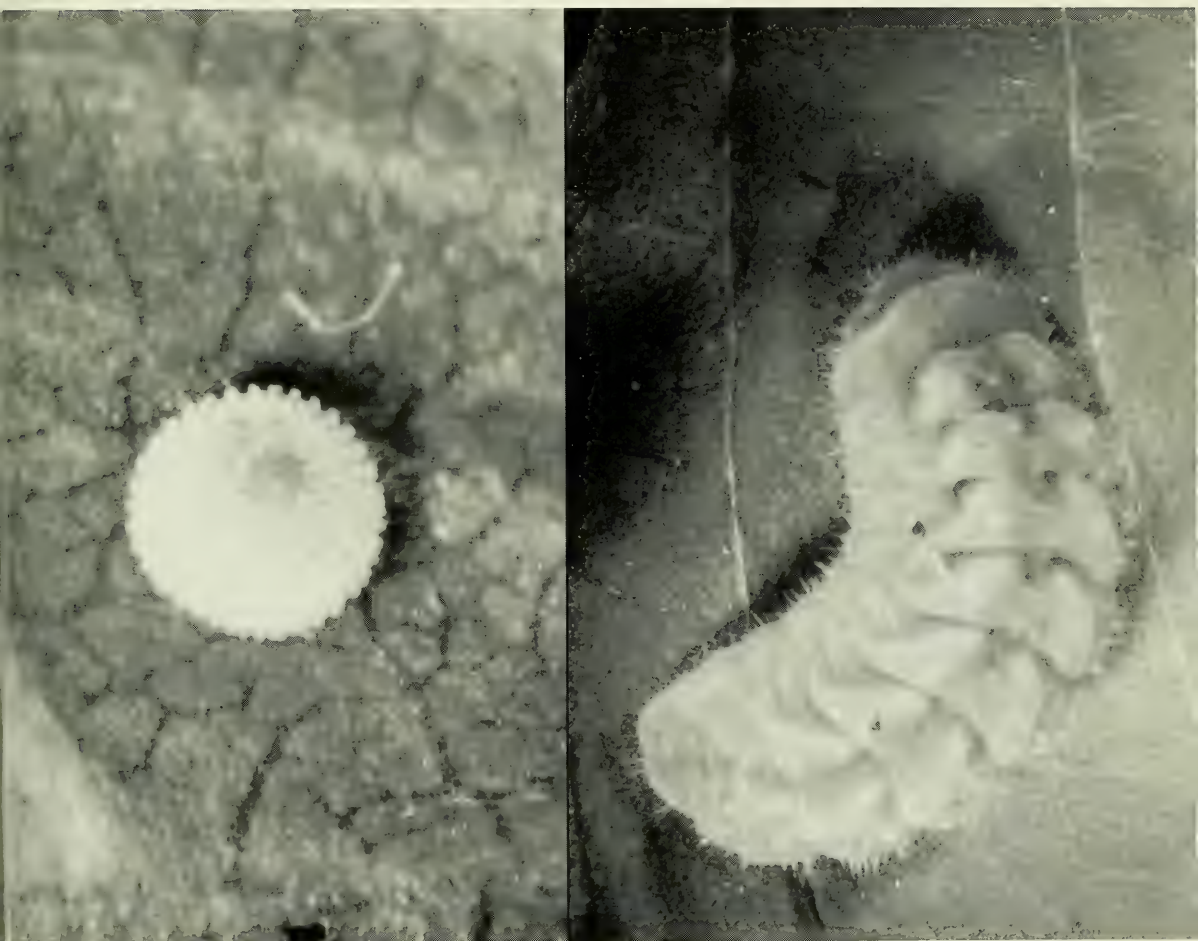
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Back Numbers and Index

Most back numbers of this journal and its predecessors, *Transactions of The Ottawa Field-Naturalists' Club*, 1879-1886, and *The Ottawa Naturalist*, 1887-1919, and *Transactions of The Ottawa Field-Naturalists' Club and The Ottawa Naturalist – Index* compiled by John M. Gillett, may be purchased from the Business Manager.

Cover: Egg (left) and fully grown larva (right) of Henry's Elfin (*Callophrys henrici*), a previously uncommon native butterfly that utilizes the invading alien shrub, Glossy Buckthorn (*Rhamnus frangula*) as a larval foodplant. The egg is 0.6 mm in diameter. The larva is approximately 10 mm long. Both specimens are from a population occupying abandoned farmlands dominated by Glossy Buckthorn south of Leitrim, Ontario. Photos by P. M. Catling. See note by P. M. Catling, R. A. Layberry, J. P. Crolla, and P. W. Hall, pages 335-337.

Time-Activity Budget for Common Loons, *Gavia immer*, Nesting on Lake Superior

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Gostomski, Theodore J., and David C. Evers. 1998. Time-activity budget for Common Loons, *Gavia immer*, nesting on Lake Superior. *Canadian Field-Naturalist* 112(2): 191-197.

Three pairs of color-marked Common Loons (*Gavia immer*) nesting on the Lake Superior shoreline of Isle Royale National Park, Michigan, were observed from mid-May to early August of 1992 and 1993 to develop a time-activity budget which could be compared with that of loons nesting on inland lakes elsewhere. Lake Superior loons spent significantly more time moving about their territories during the pre-nesting stage than at any other time during the breeding season and significantly more time resting during the post-nesting stage than at any other time ($P < 0.05$). We present evidence that the optimal time budget for a loon in its given habitat may be relatively flexible and subject to environmental influence. Differences in loon behavior over time may reflect changing environmental conditions (e.g., changes in the prey base or water quality) and provide valuable information for conservation efforts.

Key Words: Common Loon, *Gavia immer*, time-activity budget, behavior, Lake Superior.

Determining time-activity budgets provides baseline information for comparative research and a quantitative assessment of how an animal allocates its energy to the activities necessary to sustain itself and reproduce. Orians (1961) argued that an individual's time-budget can affect its reproductive success and thus has evolutionary implications. Consequently, there should be an "optimal" time budget for an animal in its given habitat, but as no two habitats are exactly the same, the optimal time budget should be "flexible" and at least partially molded by environmental factors. Therefore, determining time-activity budgets and identifying differences in behavior over time and across geographic areas may provide insight into changing environmental conditions and assist in guiding conservation and management efforts.

Numerous authors have documented the decline of Common Loons (*Gavia immer*) in North America (e.g., McIntyre 1988; Olson and Marshall 1952; Titus and VanDruff 1981), prompting numerous studies that have focused on several aspects of the species' natural history (see Morse et al. 1993; McIntyre 1988; and Strong 1988 for reviews). Time-activity budgets have been determined for Common Loons during pre-migration (McIntyre and Barr 1983) and during the winter (Daub 1989; Ford and Gieg 1995; McIntyre 1978). McIntyre (1988) noted

that activity patterns of loons during the breeding season have not been thoroughly described.

Most studies conducted during the loon's breeding season (Munro 1945; Olson and Marshall 1952; Sjölander and Ågren 1972) were largely descriptive. Dulin (1988) provided some of the first quantitative behavioral data for Common Loons during the post-nesting stage of the breeding cycle, but the lack of banded loons anywhere (McIntyre 1988) hindered efforts to conduct long-term observations of loon pairs that could be used to quantify breeding-season behavior and identify sexual role differences. Evers (1993a), after developing a safe and time-efficient method for color-banding adult loons, began conducting annual behavioral observations of nesting pairs at the Seney National Wildlife Refuge (Schoolcraft County, Michigan) and has since provided the most comprehensive information on the time-activity budget of breeding loons (Evers 1994). However, an animal's optimal time-budget may differ with changing environmental factors (Orians 1961). Differences in water quality and particularly prey base may make the time-budget of loons nesting on an inland lake or shallow pool, such as those studied by Evers (1994), different from loons that nests on Great Lakes waters.

Approximately 40% of the breeding loon population in Isle Royale National Park nests in coves and

bays of the Lake Superior shoreline (Gostomski 1997), making them unique in being the only loons known to nest on any of the Great Lakes waters (Evers, unpublished data). In 1991, Evers (unpublished data) banded nine adult loons comprising five breeding pairs along Isle Royale's northeast shoreline. Focusing on three of these pairs, behavioral observations were conducted during 1992 and 1993 to fulfill two objectives: (1) to determine the time-activity budget of loons nesting on the Lake Superior shoreline, and (2) to compare the time-budget of Lake Superior loons with inland pairs studied by Evers (1994).

Study Area and Methods

Isle Royale National Park, Keweenaw County, Michigan, (48°N, 89°W) is in Lake Superior 118 km (73 mi.) northwest of Michigan's Keweenaw Peninsula. It is a roadless archipelago composed of more than 200 islands and encompassing 544 km² of land and water. Nearly all the land-base (99%) is federally designated wilderness. Bordered by 740 km of Lake Superior shoreline and containing more than 40 interior lakes, Isle Royale provides ideal nesting habitat for an average of 41.5 pairs of breeding loons (Gostomski 1997). Many of the interior lakes are used by nesting loons, which experience complete isolation there from human disturbance. On Lake Superior, the irregular shoreline includes a number of protected harbors and coves with islands that are used by many loon pairs for nest sites. The islands, coupled with the length of the harbors, offer protection to nests against the destructive potential of both wind and waves.

Using a continuous sampling method (Tacha et al. 1985), three pairs of color-banded, nesting Common Loons were observed on the northeast end of Isle Royale National Park at Moose Point, Emerson Island, and Lane Cove from mid-May to early August of 1992 and 1993. Adults were identified by a unique combination of one or two colored bands per leg which were viewed most easily during preening and during the foot-waggle, a behavior exhibited just before resting. Banded birds were usually identified within 30 minutes after initial observation.

The breeding season was divided into pre-nesting, nesting, and post-nesting stages with associated behaviors designated for each stage (Evers 1994). Nine behavioral categories were designated for the pre-nesting stage: (1) courtship, (2) nest-building, (3) foraging, (4) locomotion, (5) resting, (6) preening, (7) agonistic interaction, (8) intrapair interaction, and (9) out-of-sight. Activities classified as Intrapair Interaction differed from behaviors exhibited by pairs simultaneously (e.g., locomotion) by involving some type of intrapair vocalization such as a "mew" call or an exchange of hoots. These vocalizations are antagonistic and generally given as contact calls

between members of a breeding pair (McIntyre 1988). Eight behavioral categories were designated for the nesting stage, when courtship and nest-building were omitted and incubation was added. Eight categories were also used during post-nesting, when incubation was replaced by chick-feeding.

The temporal sampling scheme used in 1992 followed methods developed by Evers (1994), dividing the daylight hours into three time periods: (1) dawn to 4 hours after (morning), (2) the middle 4 hours of the day (afternoon), and (3) the final 4 hours of daylight (evening). Each pair was to be observed for one six-hour period per week, using a randomly determined, rotating schedule. However, inclement weather or otherwise unsafe boating conditions prevented achievement of this goal. In 1993, a slightly different sampling schedule was established to compensate for logistical difficulties encountered in 1992. The time periods used in 1993 were: (1) morning from 0600 to 1200 E.D.T.; (2) afternoon from 1200 to 1600; and (3) evening from 1600 to 2200. Using these time periods, pairs were observed for two, randomly determined three-hour blocks. The goal was six hours of total observation per pair per week, though inclement weather again prevented this. A total of 112 hours of observation was achieved for 1992 and 1993. Pairs were observed for a total of 11 hours during the pre-nesting stage, 89 hours during nesting, and 12 hours during the post-nesting stage.

Territories were accessed by a combination of hiking and canoeing, but all observations were conducted from shore using a pair of 8 × 40 binoculars and a tripod-mounted 15-60× spotting scope. Remote observations were necessary to minimize observer bias which has been shown to affect not only the behavior of birds but also nesting success (Bradley 1985; Götmark 1992).

The heterogeneous nature of the shoreline, the often large size of territories, and the presence of islands within the territories, often prevented continuous visual contact with an individual bird. Attempts to follow loons on the water might result in an observer bias as the bird attempts to elude the observer rather than performing normal activities. Attempts to move to a better location on shore were usually impossible due to the often-thick shoreline vegetation.

Time-budget data were normalized using arcsine transformation (Zar 1984) before statistical analysis. Each behavioral category was then analyzed individually using a two-way ANOVA to determine differences between group means for breeding stage and sex. The sample size was insufficient to test for differences between the three diurnal time periods. Significant differences ($P < 0.05$) revealed by the ANOVA were then analyzed using the Student-Newman-Keuls (SNK) test (Zar 1984). The data pre-

sented below are untransformed mean percent-time values.

Results and Discussion

Time-budgets for males and females at all three sites were generally similar. Ideally, out-of-sight data should have been eliminated from analysis. However, discounting the out-of-sight data would have further confounded time-budget analysis because unequal proportions of time were spent out-of-sight by males and females. Throughout the breeding season, females were out-of-sight significantly more often than males ($F = 5.24$, $P < 0.05$, $df = 38$). Consequently, the out-of-sight data were not eliminated, and the following results and discussion focuses on the three most common behaviors exhibited while the birds were in sight.

Locomotion, resting, and foraging were the three most common behaviors, respectively, for both males and females during the pre-nesting stage (Figure 1). Locomotion was observed significantly more often at this time than during any other stage (30% for males, 19% for females; $F = 3.65$, $p < 0.05$, $df = 38$). Due to this high rate of locomotion, both males and females were out of sight significantly more often during pre-nesting (38% for males, 49% for females; $F = 6.10$, $p < 0.05$, $df = 38$).

Locomotion may have been necessary to establish and maintain a territory, given presence of multiple pairs in the area. Evers (1994) reported significantly more locomotion by loons at Seney NWR prior to nesting than during any other stage, and he similarly suggested that pairs were actively searching for suitable nest sites at that time.

It is also possible that pairs were moving about more frequently at that time as a means of establishing a pair-bond. Breeding pairs do not remain together during the winter (McIntyre 1978), and breeding populations in the southern part of the range do not make the northward migration together. Consequently, males usually arrive on nest lakes a few days before females, and pair-bonding occurs there once the females arrive (Evers, unpublished data; McIntyre 1988). McIntyre (1988) reported that pairs typically move about their territories, feed, and preen together prior to nesting. Loons observed on Isle Royale ranged over a large area during the pre-nesting stage and often did so in the company of their mates.

To the contrary, however, in more northern latitudes where the melting of ice on territorial lakes occurs later in the season, loons stop over on southern waters until warmer temperatures signal the time to move on. Munro (1945) observed flocks of loons on lakes in southern British Columbia prior to their arrival at his study site in the Cariboo Parklands farther north. Similarly, loons are thought to form flocks on the southern Great Lakes before moving farther north (Ewert 1982). If males are detained on the southern Great Lakes, and migrating females arrive before the males can continue on, the pair bond may be established there. The pair will then complete the remainder of the northern migration together (McIntyre 1988). In that case, it would be expected that lower rates of locomotion would be observed during the pre-nesting stage. However, the lack of time-budget studies for loons farther north than Isle Royale prevents any comparison to support this hypothesis.

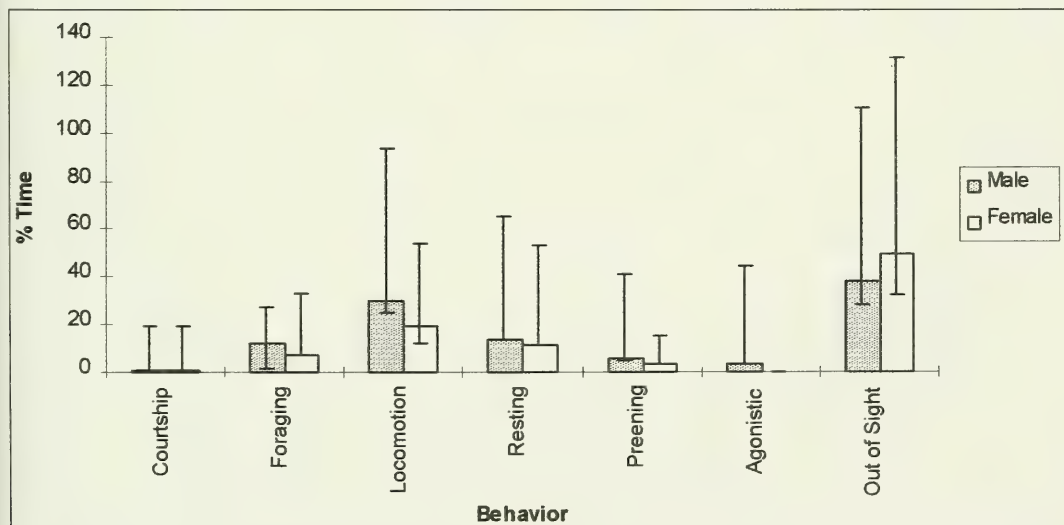


FIGURE 1. Time-activity budget (mean % time) for Lake Superior shoreline Common Loons during the pre-nesting stage, 1992-1993. $N = 2$ territories.

The convoluted Lake Superior shoreline probably provides adequate visual isolation between territories, thereby reducing the probability of territorial encounters (Strong and Bissonette 1988). Consequently, it may be that loons are not moving about to establish territories, but instead are pair-bonding and/or searching for nest sites as suggested by Evers (1994).

Males spent slightly more time foraging (12% -vs- 7%) and resting (14% -vs- 11%) than females during the pre-nesting stage, perhaps because of their greater investment in territorial defense (agonistic encounters, 3% -vs- 0; Figure 1).

Courtship and copulation between loons is subtle and was observed twice during this study only through chance encounters. As expected, incubation was the most frequent activity during the nesting stage for both males and females (58% and 51%, respectively) (Figure 2). Males incubated during most of the afternoon and evening hours, and females were predominantly on the nest during the morning (Table 1).

No definite nest-exchange schedule could be delineated for Lake Superior loons, but male loons on Isle Royale were typically found on the nest in early evening, whereas females tended to be incubating in early morning. This suggested that pairs exchanged positions after sunset, allowing males to patrol the territory. McIntyre (1988) stated that, though a stereotypical exchange pattern probably does not exist, loon pairs regularly exchange incubation duties. She suggested that males may patrol the territory at night while their mates are incubating,

TABLE 1. Diurnal distribution of incubation rates (in percent-time) for Common Loons on the Lake Superior shoreline of Isle Royale NP, 1992–1993. N = 3 territories.

Sex	Morning	Afternoon	Evening
Male	61	121	130
Female	124	51	55

and then exchange places on the nest sometime after sunrise. The advantage to be gained from that type of rotation is the ability of the male to defend the territory at night by using the yodel vocalization, which is an aggressive call given only by males (Rummel and Goetzinger 1975). Conversely, Evers et al. (unpublished data) reported that loon pairs at Seney NWR exchanged incubation duties at least once during the evening, suggesting that males play some role in incubating the eggs at night.

Foraging was the second most common behavior of females during the nesting stage and rates increased slightly from the pre-nesting stage (7% to 11%, respectively). Males spent less time foraging than during the previous stage, instead dividing their time equally between foraging, moving about their territories, and resting (8% each).

During the nesting stage, loon territories become compressed and activities are concentrated primarily around the nest site (McIntyre 1988). Indeed, Lake Superior loon pairs moved about less frequently (third most prevalent behavior for both sexes at 8% each), and consequently were out-of-sight less often.

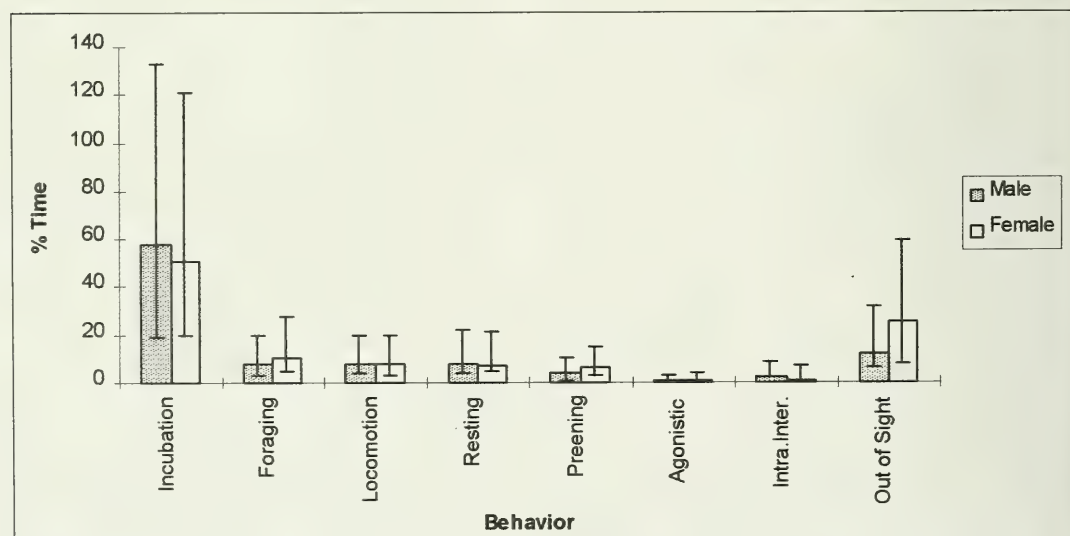


FIGURE 2. Time-activity budget (mean % time) for Lake Superior shoreline Common Loons during the nesting stage, 1992–1993. N = 3 territories.

Loons spent significantly more time resting during the post-nesting stage than at any other time ($F = 8.24$, $P < 0.05$, $df = 35$), and it was the primary activity for both males and females (31% each; Figure 3). The significant amount of time spent resting by the adults during this stage may be interpreted as a recuperative effort after having reached the final stage of breeding, but it may also reflect preparation for fall migration. At the same time, the chicks remained dependent on their parents for food, and the adults continued to allocate a large portion of time towards feeding their young.

Chick-feeding was the second most common activity for both sexes, with slightly more time invested by females than by males (28% -vs- 24%). Both Dulin (1988) and Evers (1994) reported female-biased feeding of the young until the fourth week, after which both parents fed them equally. However, Evers (unpublished data) has also noted that there is some pair and sex variation in feeding and foraging times for chick rearing, and consequently, it is probably safe to conclude that males and females share responsibility for raising and feeding young.

Among the other loon species, Reimchen and Douglas (1985) recorded Red-throated Loon (*Gavia stellata*) pairs making similar numbers of foraging flights for their young one-to-six days after hatching, after which the contributions of the female increased while male efforts declined. Pacific Loon (*Gavia pacifica*) pairs also fed their young at different rates but both males and females displayed an increase in rate of feeding as the young grew older (Petersen 1989).

Foraging ranked third for females during post-nesting, (4%), whereas males spent more time locomoting (Figure 3). Out-of-sight rates slightly increased for both sexes as family units moved to nurseries (McIntyre 1983; Strong and Bissonette 1989) with their young and generally began to range over larger areas. Family units were never directly observed moving to nurseries. Consequently, the time spent trying to locate them, compounded with physiographic barriers that made nurseries difficult to observe, resulted in a minimal number of observations during that stage.

The Flexible Optimal Time Budget

Behavioral differences between loons nesting on the Lake Superior shoreline and those that nest on inland waters may lend support to Orians' (1961) concept of a flexible optimal time budget. To illustrate this, we compared the time budget of Lake Superior loons with the time budget determined by Evers (1994) for loons nesting on pools within the Seney National Wildlife Refuge (NWR) in Schoolcraft County, Michigan. Unfortunately, comparisons could only be speculative because differences in sample sizes between Evers' (1994) study and this one prevented statistical analysis.

Like the Lake Superior loons, pairs at Seney spent significantly more time locomoting during the pre-nesting stage than at any other time, and they rested significantly more during the post-nesting stage (Evers 1994). However, one striking difference between birds at the two sites was found.

Comparison of foraging rates for loons on Lake Superior and at Seney during the pre-nesting and

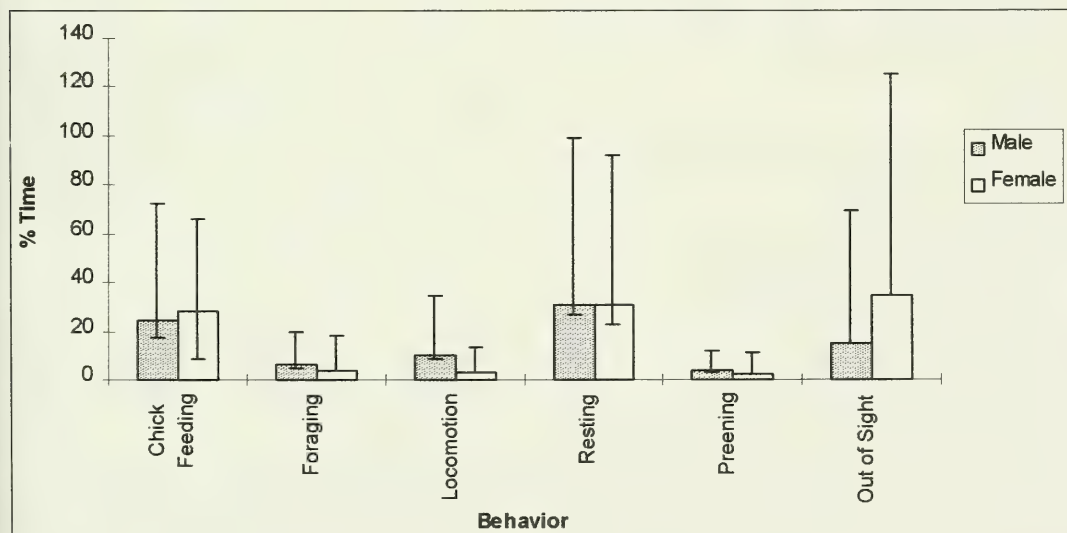


FIGURE 3. Time-activity budget (mean % time) for Lake Superior shoreline Common Loons during the post-nesting stage, 1992-1993. $N = 2$ territories.

nesting stages for 1992 and 1993 revealed marked differences which may reflect differences in water quality (clarity) and the prey base at the two locations. Evers (1994) reported foraging rates ranging from 32% to 82% (\bar{x} = 58%) for loon pairs at Seney during the pre-nesting stage, whereas Lake Superior shoreline pairs were observed foraging from 6% to 13% at that time (\bar{x} = 9.5%). During the nesting stage, foraging rates for Seney loons were still higher (9% to 40%, \bar{x} = 24.5%) than for loons on Lake Superior (8% to 14%, \bar{x} = 10.5%).

The pools at Seney NWR are shallow (1-2 m in depth), and the water column is generally stained due to the input of tannins from terrestrial vegetation. White Sucker (*Catostomus commersonii*), Yellow Perch (*Perca flavescens*), and Pumpkinseed (*Lepomis gibbosus*) all occur in the pools, but it is the Brown Bullhead (*Ictalurus nebulosus*), a bottom-feeding species, that makes up > 95% of the fish biomass in the pools and comprises the majority of the adult loon's diet (Evers, unpublished data). Conversely, the coves and harbors of Isle Royale's shoreline are deep (1-16 m in depth), but the water is clear. Fish species include perch and suckers, but Lake Herring (*Coregonus artedii*), a schooling species, can easily be seen moving through the water column at a variety of depths (Gostomski, personal observation; Shelton 1975).

As visual predators, loons commonly "peer" below the water's surface in search of prey before diving in pursuit (McIntyre 1988). For a visual predator, it would be less energetically expensive to feed on a school of fish in a clear water column than on a bottom feeder in tannin-stained waters. It is likely that Lake Superior loons can catch their fill and spend less time doing so than the Seney loons which may have difficulty seeing their prey as well as catching them. The difference in foraging rates between the two sites appeared to support this hypothesis.

In conclusion, McIntyre (1988) reported that loon pairs remain together almost constantly during the breeding season, implying that they exhibit similar time-budgets. This appeared to be true also for loons nesting on the Lake Superior shoreline. Orians' (1961) "flexible optimal time budget" was also supported, as the time-budget of inland-nesting loons differed only slightly from that of pairs on the Lake Superior shoreline.

Comparisons between Isle Royale's shoreline loons and those at Seney NWR are useful because of Isle Royale's isolation from many of the human disturbances that loons experience on the mainland. Evers (1994) stated that knowledge of time-budgets could provide a reference for addressing anthropogenic disturbances that affect loon pairs or populations. Correlating changing behavioral patterns (time-budgets) with fluctuations in reproductive suc-

cess may allow resource managers to interpret trends in loon productivity and population growth more accurately. To this end, behavioral monitoring projects could focus on foraging rates, duration of incubation bouts, and frequency of agonistic encounters with conspecifics or even humans. Some of these projects have already been initiated (e.g., incubation and nest exchange patterns, Paruk *in preparation*; agonistic encounters Piper et al. 1997). Foraging rates could be used to evaluate the available food resources, and the frequency of agonistic encounters coupled with the duration of incubation bouts would provide an indication of the degree of disturbance to loon pairs during nesting. Such a project would complement that of Titus and VanDruff (1981) by focusing on behavior instead of productivity alone and by providing information on the quality of the available habitat.

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Response of a Forest Raptor Community to Broadcasts of Heterospecific and Conspecific Calls During the Breeding Season

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We investigated the response of the forest raptor community to broadcasts of all potentially occurring raptors in a New Jersey watershed. Raptors were systematically surveyed using high-volume broadcasts of conspecific and heterospecific calls during the breeding season at a total of 81 survey stations. Results showed 107 responses from 10 species of breeding raptors following 891 broadcasts of 11 species. Among responses that occurred during or after broadcasts, at least 50% of the forest raptor species responded to heterospecific calls. Response rates to conspecific or heterospecific broadcasts were significantly different between hawks (68% heterospecific) and owls (26% heterospecific), suggesting that hawks showed greater heterospecific conflict than members of the owl guild. The hawk guild had a higher species packing (six versus four species) which is thought to increase the likelihood of competition in the community. In addition, most hawks probably need to re-establish territories each spring because the vast majority of them will migrate south for the winter. In contrast, most of the owl guild members are permanent residents and territories may be more permanent. Overall, the prevalence of heterospecific response is an indicator that current competition exists and continues to shape present-day community structure among forest raptors.

Key Words: raptors, hawks, owls, community, forest, survey, behavior, vocalizations.

Few studies of complete raptor communities (diurnal and nocturnal) have been made (Craighead and Craighead 1956; Smith and Murphy 1973; Bosakowski and Smith 1992) despite the prominence of raptors as competing predators (Schoener 1984). Most studies of ecological communities typically involve considerations of resource partitioning in which a community is inspected for differences in resource use (Schoener 1974). Differences are then used to explain the current state of species abundances (species packing) in the study area and how these differences in resource use allow co-existence or permit sympatry. Within this conceptual framework, competition is believed to be central because it acts to exclude similar species from certain communities (limiting similarity - MacArthur and Levins 1967) and facilitates co-existence in others through niche partitioning (Schoener 1974).

For top predators (such as raptors) competition should prevail as a regulator of population density, whereas predation should prevail among animals of intermediate and low trophic status (Hairston et al. 1960). According to Morse (1980), size facilitates priority of access for dominant species that can exert social dominance (interference competition) over other species. Thus, habitat segregation among guild members might result if some species are behaviorally dominant (Gorman 1988) and may not simply be the result of differential habitat selection. Nishikawa (1985, 1987) has shown that salamanders in stronger competition showed stronger aggression

to conspecific and heterospecific intruders than salamanders in weaker competition. Morse (1970) also observed considerable heterospecific aggression in mixed-species flocks of passerines and found that subordinate species were forced to forage more diversely in the presence of dominant species, thus showing an active behavioral element in shaping community structure. Cody (1973) found that avoidance was also a regular phenomenon in many bird communities.

In this paper, we report on a high frequency of responses from sympatric breeding forest raptors to broadcasts of heterospecific calls. Such responses may suggest the existence of current competition among sympatric species which may have major implications for the nesting density, reproductive output, and habitat selection of all raptor species within the community. If species are investing energy into repelling heterospecifics (e.g., skirmishing, escorting, mobbing, calling), then the threat of current competition is the most likely explanation, except in the case of defending young. Conversely, the null hypothesis is: species should be expected to ignore the vocalizations of other guild members in the community if they are not subject to competition or predation.

Study Area and Methods

The study area was in the Pequannock Watershed in Passaic, Morris, and Sussex counties. The study site, approximately 16 000 ha, includes some of the

last remaining wilderness in the northern half of New Jersey. This hilly, mostly forested terrain is part of the Eastern Deciduous Forest Biome (Shelford 1963). Nearly all of the forests are second-growth forest (Ohmann and Buell 1968; Russell 1981), 40 to 80 years old, dominated by oaks (*Quercus* spp.) and other sub-climax hardwood trees (Buell et al. 1966; Russell 1981). Older forest (100+ years) is rare and is typically limited to small remnant stands surrounded by younger forest. About 75 percent of the forest is deciduous, about 20 percent consists of Eastern Hemlock (*Tsuga canadensis*) — White Pine (*Pinus strobus*) stands, and 5 percent is mature conifer plantations. Residential and commercial development is limited to less than 10 percent of the study area. Aquatic habitats include five major reservoirs, several smaller impoundments, Beaver (*Castor canadensis*) ponds, marshes, shrub swamps and wooded swamps, the latter occurring in many areas.

The survey design consisted of a grid of 81 broadcasting stations spaced at approximately 1.2 km intervals. The spacing of stations was chosen to avoid overlap with neighboring stations and was roughly equivalent to the minimum nearest-neighbor nest distance for Red-shouldered Hawks (*Buteo lineatus*) that we found in preliminary studies. Surveys were conducted on fair-weather days with low wind velocity (< 15 km/hr) and no precipitation.

Tapes of raptor vocalizations were broadcast at high volume on a portable cassette tape deck ("boom box") powered by 8 "D" cell batteries with a 10-watt output. The unit had two detachable speakers that we mounted back-to-back to provide bidirectional broadcasting of vocalizations at all times. During broadcasts, the back-to-back speakers were hung on low tree branches about 1.5 m above ground. To avoid the effect of human presence on the response behavior of raptors, we made observations about 10 to 20 m from the speakers from partially concealed positions and wore camouflaged clothing.

On each survey, tape-recorded vocalizations of a maximum of three raptor species were played during an 18-minute period. Vocalizations of each species were recorded on cassette tape for a 3 min period followed by a 3 min period of silence. The silent period served a dual function as a listening/watching period for vocal or visual responses of raptors and also as a refractory period prior to broadcasts of the next raptor species. To reduce the number of surveys required to survey the 11 potential species, vocalizations of two to three hawk or owl species were broadcast on each survey, resulting in a total of two night surveys for owls and two daytime surveys for hawks.

The selection of species for each survey was based on regional nesting phenology (Bull 1964; Bosakowski et al. 1989b; Speiser and Bosakowski

1991; Bosakowski 1990). Broadcasts were ordered from the smallest to the largest raptor, to avoid potential inhibitory effects of large raptor on the response behavior of smaller species (Call 1978). Two surveys were conducted at night for five owl species. These surveys began at least a half-hour after sunset and were terminated by 01:00. The first owl survey was conducted from 21 March 1989 to 16 April 1989 for Eastern Screech-Owls (*Otus asio*), Long-eared Owls (*Asio otus*), and Great Horned Owls (*Bubo virginianus*). Species on the second owl survey conducted from 16 April to 19 May 1989 included the Northern Saw-whet Owl (*Aegolius acadicus*) and Barred Owl (*Strix varia*). Hawk surveys were conducted from at least 2 hours after sunrise to no later than 2 hours before sunset. Species included on the first hawk survey conducted from 7 April to 4 May 1989 included the Red-shouldered Hawk, Northern Goshawk (*Accipiter gentilis*), and Red-tailed Hawk (*Buteo jamaicensis*). The second hawk survey from 18 May through 20 June 1989 included the Sharp-shinned Hawk (*Accipiter striatus*), Cooper's Hawk (*Accipiter cooperii*), and Broad-winged Hawk (*Buteo platypterus*).

Results and Discussion

Community Structure

Ten species of raptors were detected during the breeding season, including four owl species and six hawks with a grand total of 107 detections during 891 broadcasts (Table 1). Previous studies suggested a maximum of 11 possible species in the study area (Benzinger et al. 1988; Bosakowski et al. 1989a). Northern Saw-whet Owl was not detected, but it was a rare breeder in the study area.

One or more species of raptors was found at 61 of the 81 survey stations including one or more species of owls at 40 stations (47 detections) and one or more hawk species detected at 48 stations (67 detections). Overall, hawks comprised 59 percent of the total detections (Table 1). Among owls, Barred Owl and Great Horned Owl were the numerically dominant breeding species. Eastern Screech-Owl and Long-eared Owl occurred in small numbers. Many studies have shown that the two larger species regularly prey on the two smaller species (Errington 1932; Bent 1938; Rusling 1951; Craighead and Craighead 1956; Orians and Kuhlman 1956; Bosakowski et al. 1989b).

The hawk guild consisted of six breeding species. Red-tailed Hawk response was highest followed by Broad-winged Hawk, Cooper's Hawk, and Red-shouldered Hawk. Northern Goshawk was detected at two stations and Sharp-shinned Hawk was detected only once. Similar to our findings, Jaksic (1983) reviewed studies on five complete raptor assemblages and noted that at each location, hawk species always outnumbered owls. However, E. D.

TABLE 1. Response of forest raptors to broadcasts of conspecific and heterospecific vocalizations at 81 broadcast stations. Species acronyms: ESOW = Eastern Screech-owl, LEOW = Long-eared Owl, GHOW = Great Horned Owl, NSOW = Northern Saw-whet Owl, BAOW = Barred Owl, RTHA = Red-tailed Hawk, RSHA = Red-shouldered Hawk, NOGO = Northern Goshawk, BWHA = Broad-wing Hawk, SSHA = Sharp-shinned Hawk, COHA = Cooper's Hawk.

Species Broadcasted		Species Responding						
Survey	Owls	ESOW	LEOW	GHOW	NSOW	BAOW		
1st	ESOW	3	—	1	—	1	Totals 31 11 5 47	
1st	LEOW	—	2	2	—	—		
1st	GHOW	—	—	7	—	—		
2nd	NSOW	—	—	2	—	4		
2nd	BAOW	—	—	1	—	19		
Conspecific Responses		3	2	7	0	19		
Heterospecific Responses		0	0	6	0	5		
Pre-broadcast Responses		0	0	3	0	2		
Total		3	2	16	0	26		
Survey	Hawks	RSHA	NOGO	RTHA	SSHA	COHA	BWHA	
3rd	RSHA	4	—	8	1	3	2	
3rd	NOGO	—	—	5	—	—	1	
3rd	RTHA	2	1	4	—	—	1	
4th	SSHA	1	—	—	—	2	2	
4th	COHA	1	—	1	—	4	2	
4th	BWHA	3	—	1	—	1	6	
Conspecific Responses		4	0	4	0	4	6	
Heterospecific Responses		7	1	15	1	6	8	
Pre-broadcast Responses		1	1	4	0	0	5	
Total		12	2	23	1	10	19	
		Totals 18 38 11 67						

Forsman (personal communication) has observed that owls always outnumber hawk species in Pacific Northwest forests.

Type of Response

The percent of responses that were vocal (as opposed to silent) was much greater in the smaller hawk species (Cooper's Hawk 78%, Broad-winged Hawk 57%, and Red-shouldered Hawk 58%) compared to the Red-tailed Hawk (21%), the largest member of the hawk guild. Balding and Dibble (1984) also found that vocal response was lowest in Red-tailed Hawk compared to the smaller Red-shouldered Hawk and Broad-winged Hawk. The Red-tailed Hawk may exert a social dominance by virtue of its conspicuous soaring flights over the canopy. Visual territorial displays are commonly used by other large soaring raptor species such as the Golden Eagle (*Aquila chrysaetos*) (Bergo 1987).

The three smallest hawks were closest in size and were more vocally aggressive, which might be expected if they are close competitors (Nishikawa 1987). If, as Nishikawa (1985, 1987) suggested, heterospecific aggression varies with the intensity of competition, then broadcasts of vocalizations may be useful in surveying hawk guilds when information is also desired about the relative abundance of each of the potentially competitive species. Red-shouldered and Broad-winged hawks were more vocal, but also called primarily in flight from immediately above the canopy or from a concealed position, high within the canopy. The more agile Cooper's Hawk, frequently responded by flying towards and landing within 10-30 m of the speakers and proceeded to "cackle" (Bent 1937) loudly in response to the broadcasts. Ninety percent of responses by Cooper's Hawks were confined below the canopy excepting once when a bird cackled while circle soaring over the broadcast site.

Silent, as opposed to vocal, response rates of owls could not be reliably obtained, although initial "fly-overs" were observed in as many as 12.5% of the responding Great Horned Owls and 37% of the Barred Owls prior to landing and calling from nearby locations. Responses of both Eastern Screech-Owls and Barred Owls were always from within the canopy whereas Great Horned Owls and Long-eared Owls often responded from conspicuous edge sites adjacent to fields, reservoirs, or open wetlands. Only Great Horned Owls vocalized from the tops of tall canopy trees.

Response Rates to Conspecific and Heterospecific Calls

Response to conspecific broadcasts during the breeding season are most likely a result of territorial defense (Smith et al. 1987). They may also be due to the misidentification of a mate's call or to mate-seeking in unpaired birds. However, Forsman et al. (1977) believed that only breeding Spotted Owls

(*Strix occidentalis*) responded vigorously to broadcast calls of conspecifics. In this study, recordings of five owl species and six hawk species were broadcast at each site which also permitted an assessment of response to heterospecific calls which has been infrequently studied in raptors (Balding and Dibble 1984; Kimmel and Yahner 1990).

Of all detections occurring during or after broadcasts in our study area, at least 50% of the raptor community responded to broadcasts of heterospecific calls (Table 1). During owl surveys, 31 responses to conspecific broadcasts were detected and 11 responses followed heterospecific broadcasts (26%). During hawk surveys, 18 responses to conspecific broadcasts were detected and 38 responses followed heterospecific broadcasts (68%). Response rates to conspecific or heterospecific broadcasts were significantly different between hawks and owls (Fisher Exact Test, $p < 0.001$), suggesting that hawks showed a greater tendency towards heterospecific conflict than did members of the owl guild.

Seasonal stability of home ranges could be an important distinguishing factor between the response differences of hawks and owls. Owls in the study area were largely permanent residents (Bent 1938; Bull 1964; Johnsgard 1988) and the two larger species can survive up to 18 to 20 years in the wild (Klimkiewicz and Futcher 1989). In contrast, most of hawk guild is migratory (Bull 1964), except possibly for some Northern Goshawks (Speiser and Bosakowski 1991). Hence, in spring, most newly arriving hawks must re-establish their old territories and may have to compete actively with an excess load of passing migrants trying to fill-in the available habitat.

In the owl guild, territories are typically maintained year-round (Fuller 1979; Smith and Gilbert 1984; Johnsgard 1988), and therefore, territorial calling is probably not needed as frequently to repel intrusion from other owls. Despite the abundance of Barred Owl and Great Horned Owl, the lack of spatial overlap (only two sites) and rarity of heterospecific response (none for Barred Owl vs. Great Horned Owl call, one for Great Horned Owl vs. Barred Owl call) suggests stability of territorial boundaries. Possibly, a dominance-avoidance system of Great Horned Owl over Barred Owl is regulating spacing and reducing conflict. Fuller (1979) demonstrated remarkably small overlap ($< 1\%$) of home ranges between adjacent nesting territories of Barred Owl and Great Horned Owl during periods up to 35 days during the breeding season, although larger overlap was noted when comparing annual home ranges.

Curiously, both large owl species in this study were more likely to be attracted to broadcasts of smaller owl species (Long-eared Owl, Eastern Screech-Owl, Northern Saw-whet Owl) than between each other (Barred Owl versus Great

Horned Owl). It is doubtful that their intent was predation on the smaller owl species as the large owls usually responded excitedly with an extensive bout of territorial hooting, and little stealth was exhibited if they approached the broadcast site. Conversely, Eastern Screech-owls will frequently respond excitedly to vocal imitations and broadcasts of Great Horned Owl calls during mid-winter (Bosakowski and Benzinger, unpublished data) and frequently they would dive at our heads if we were doing the hooting. Obviously, these owls are not defending young, but are still intent on driving-out or mobbing the intruding Great Horned Owl (at the risk of being caught). These small owls appear to maintain small feeding territories within the much larger Great Horned Owl territory which means that their heterospecific response could be motivated more by competition than avoidance of predation.

Another possible explanation for the greater heterospecific conflict in the hawk guild could be misidentification (Murray 1981) of heterospecific hawks as conspecifics. However, this theory is not likely given the diverse vocalizations of these species and the keen song recognition abilities of birds (Marler and Hamilton 1966). More likely, is the fact that this guild has a higher species packing which could potentially intensify competition (Begon et al. 1986), and lead to greater heterospecific aggression (Nishikawa 1987). Furthermore, lack of substantial size differences (morphological differentiation or Hutchinsonian spacing) among the three smaller hawk species coupled with higher dietary overlap within the hawk guild (Bosakowski and Smith 1992) predicts that competition-mediated aggression would be more strongly evoked than within the owl guild.

Heterospecific Aggression: Evidence for Current Competition

Newton (1979) believed that most raptor species do not defend territories against heterospecifics, but noted several exceptions including the Red-tailed Hawk and Red-shouldered Hawk. Schmutz et al. (1980) found that inadequate spacing between nest sites of three *Buteo* species resulted in decreased reproductive output ("reduced fitness"), which suggests that interspecific competition can be a current phenomenon in raptor communities. Although heterospecific response was found to be common during our study (50% of responses), the vast majority of interspecific interactions, display flights, and territorial protests probably go unreported during the breeding season. We contend that these important behavioral patterns could account for the "negative distributions" (Begon et al. 1986) typically observed among many heterospecific raptors in the same community (Craighead and Craighead 1956; Smith and Murphy 1973; Bosakowski 1990) and could influence the overall habitat characteristics associat-

ed with each species. Gorman (1988) found that habitat segregation among stream fishes was modified by heterospecific aggression. Similarly, habitat partitioning among forest raptors could be a complex combination of dynamic partitioning (dominance-avoidance) and static partitioning (habitat selection from "the ghost of competition past" — Connell 1980). The general pattern of niche overdispersion among most raptors in this community (Bosakowski 1990; Bosakowski and Smith 1992) could be the result of differential habitat selection and the ghost of competition past (morphological differences resulting in differential prey utilization). However, the prevalence of heterospecific response seems to indicate that a current element of competition still continues to shape present-day community structure.

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Lead Poisoning of Trumpeter Swans, *Cygnus buccinator*, in British Columbia, 1976-1994

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Lead poisoning from ingestion of lead shot is a cause of death of Trumpeter Swans (*Cygnus buccinator*) wintering on the southern coast of British Columbia. Between 1976 and 1994, 186 Trumpeter Swans were found either dead or sick in British Columbia; 87 (47%) were diagnosed with acute lead toxicosis. The largest die-off of 32 Trumpeter Swans occurred at Judson Lake in 1992. Tissues from 102 swans were analyzed for lead; 65 (64%) were classified as lead-poisoned. Lead residues detected in kidney, liver, bone, and blood samples of lead-poisoned swans averaged 30.6 mg/g, 23.7 mg/g, 18.3 mg/g and 4.4 mg/g wet weight, respectively. Ingested lead shot were detected in gizzards of 46 of the 62 lead-poisoned swans examined; number of pellets per gizzard were counted in 34 swans with an average of 16.8 pellets per bird (range:1-80, SD 17.3). Steel shot were detected in the gizzards of 18 of the 62 lead-poisoned swans examined; number of pellets per gizzard were counted in nine swans with an average of 3.3 pellets per bird (range:1-11, SD 3.2). Although the use of lead shot for waterfowl hunting has been banned in the main wintering areas of Trumpeter Swans since 1990, these birds continue to die from lead poisoning. Despite the high rate of unnatural mortality among Trumpeter Swans reported to our agency, their populations in the region currently are increasing. Lead poisoning as a threat to Trumpeter Swan populations in British Columbia is assessed.

Key Words: Trumpeter Swan, *Cygnus buccinator*, waterfowl, lead, sediment, shot, poisoning, disease, British Columbia.

Poisoning of North American waterfowl from consumption of spent lead shot has been well documented (Bellrose 1959; Sanderson and Bellrose 1986). Swans are at particular risk from lead poisoning because they consume large amounts of plant material and sediment while feeding (thereby increasing the probability of their ingesting spent shot), and possibly due to inherent genus sensitivity to lead toxicosis (Birkhead 1982; Blus et al. 1989). Lead poisoning of Mute Swans (*Cygnus olor*), Black Swans (*C. atratus*), Whooper Swans (*C. cygnus*), and Beswick's Swans (*C. columbianus bewickii*) has been reported in Europe (Wilmore 1974; Simpson et al. 1979; Clausen et al. 1982; Birkhead 1982, 1983; Spray and Milne 1988; O'Halloran et al. 1991; Sears and Hunt 1991), Australia (Kohn and Harper 1988) and Japan (Honda et al. 1990; Ochiai et al. 1993). In the United States, lead poisoning of Tundra Swans (*C. columbianus*) from ingestion of lead shot has also been reported (Trainer and Hunt 1965). Other studies from Canada reported mortality from lead poisoning in Whistling Swans (*Olor columbianus*) and introduced Trumpeter Swans in Ontario (Irwin 1975; Lumsden 1993).

Lead poisoning of Trumpeter Swans occurred repeatedly in British Columbia since at least 1925 (Munro 1925, 1949; Eklund 1946; Cowan 1946; McKelvey and MacNeill 1980). In neighbouring Washington State from 1976 to 1987, 62% of reported Trumpeter Swan mortalities were attributed to lead-shot ingestion (Blus et al. 1989). Although Tundra Swans are not common on the coast of British Columbia in winter, several cases of lead poisoning have been reported (McKelvey and MacNeill 1980). In 1990 the use of lead shot for waterfowl hunting was banned in south-western British Columbia, where there is a high concentration of Trumpeter Swans in winter. Use of lead shot for waterfowl hunting was banned in Washington State in 1991. However, in 1992 at least 32 swans died of lead poisoning in a single incident at Judson Lake on the British Columbia/Washington border, indicating that lead poisoning from ingestion of spent lead shot from past hunting is an ongoing threat. The following report assesses the threat of lead poisoning to Trumpeter Swan populations in British Columbia using published and unpublished data on Trumpeter Swan mortalities reported to the Canadian Wildlife

Service (CWS) between 1976 and 1994. The largest lead poisoning die-off which occurred during this period, the Judson Lake incident of 1992, is described in detail.

Methods

Swan mortality

Data for 186 Trumpeter Swans found dead or injured in British Columbia between 1976 and 1994 that are summarized in this report were collected from unpublished accounts archived at the Pacific Wildlife Research Centre, Canadian Wildlife Service, Delta, British Columbia, and a published report by the Island Veterinary Hospital (Langelier et al. 1989).

The amount of information collected on each mortality event varied considerably; post-mortem examinations were not conducted on all carcasses nor were tissue lead levels always measured. The cause of death was assessed based on results of the post-mortem examination and/or analytical results if available, or on the circumstances surrounding the event which were included in the incident report. If the cause of death upon initial examination was determined by the veterinarian to be a disease or trauma but subsequent tissue chemistry indicated toxic lead residues, the cause of death was listed as lead poisoning. In general, tissue chemistry was conducted in cases where the cause of death was suspected toxicosis, or was not determined from the gross post-mortem examination. For summary purposes, all of the diagnoses were separated into nine categories: (1) "lead toxicosis" included swans with acute lead poisoning as defined below; (2) "disease" included swans with nephritis, hypovitaminosis A, encephalitis, peritonitis or parasitism; (3) "starvation" included swans whose primary cause of death was inanition; (4) "infectious disease" included swans with contagious diseases such as aspergillosis; (5) "electrocution" included swans which were electrocuted; (6) "collision" included swans which were injured from colliding with an object; (7) "shot" included swans which died from gunshot wounds; (8) "trauma" included swans which had traumatic injuries other than electrocution, collision or shot; (9) "undetermined" included swans whose cause of death could not be ascertained.

We assigned lead poisoning as a cause of death if liver or kidney lead concentration was > 10 mg/g wet weight. Blood lead levels > 0.8 mg/g wet weight in swans that later died were judged to indicate lethal lead concentrations (Mauser et al. 1990). Swans also were considered lead-poisoned if lead shot were detected in the gizzard and the birds displayed clinical signs of lead poisoning such as bright green-coloured feces and emaciation (Degernes and Redig 1988). Swans with liver or kidney lead levels between 5 and 10 mg/g wet weight or blood lead levels between 0.2 and 0.8 mg/g wet weight were con-

sidered to have experienced elevated, sub-lethal lead exposure. Bone lead levels are a good indicator of life-long exposure, but do not accurately reflect recent exposure (Scheuhammer 1987) and therefore cannot be used to define acute toxicosis. We set a value of > 2 mg/g wet weight in bone as an indication of sub-lethal exposure. Swans were also categorized as sub-lethally exposed if lead shot were detected in the gizzard even though the bird exhibited no clinical signs of lead poisoning.

Prior to 1985, post-mortem examinations, including histopathological examinations, were conducted by the Agriculture Canada Health of Animals Branch, and element concentrations in liver and kidney were determined by the Environmental Laboratory of the British Columbia Ministry of the Environment (BCMOE) in Vancouver. Between 1985 and 1989, necropsies and tissue chemistry were conducted by Animal Health Centre Laboratory of the British Columbia Ministry of Agriculture Fisheries and Food (BCMAFF) in Abbotsford. After 1989, some swans were examined and tissue chemistry conducted by the BCMAFF; other swans were necropsied by the Island Veterinary Hospital and tissue chemistry measured by the BCMAFF or lead residues in kidney, liver, bone and/or blood were determined by the Canadian Wildlife Service (CWS) at the National Wildlife Research Centre (NWRC) in Hull, Quebec.

Elements including lead (Pb), iron (Fe), selenium (Se), copper (Cu), zinc (Zn), manganese (Mn), cadmium (Cd), calcium (Ca) and magnesium (Mg) were quantified in liver and kidney samples by the BCMOE using graphite furnace atomic absorption spectrophotometry (GFAAS) and by BCMAFF using flame atomic absorption spectrophotometry (AAS). The practical detection limit (DL) ranged from 2 to 5 mg/g wet weight depending on the element and method. The CWS measured lead residues in kidney, liver and bone by flame AAS. When required, detection was improved by employing a modification of flame AAS using an atom concentrator tube (ACT-80, Varian) or by using GFAAS. Blood lead was determined by GFAAS (Fernandez and Hilligoss 1982). The DL of lead in kidney ranged from approximately 0.1 to 17 mg/g dry weight (which equals 0.03 to 5.03 mg/g wet weight using 70.4% moisture, the average moisture content of Trumpeter Swan kidneys determined from our database) depending on the method used. In liver it was 0.2 to 17 mg/g dry weight which converts to 0.05 to 4.0 mg/g wet weight, based on a 76.5% average moisture content. In bone it was 0.8 to 1.4 mg/g dry weight (0.7 to 1.2 mg/g wet weight, 14.6% moisture) and in blood it was 0.06 mg/g dry weight (0.01 mg/g wet weight, 82.7% moisture). Tissue element concentrations are expressed on a wet weight basis, calculated from dry weight using the individual moistures.

Judson Lake incident, 1992

Judson Lake is a shallow, marshy body of water approximately one kilometre in length located at the Canada/United States border south of Abbotsford, British Columbia (49° 00', 122° 21'). The lake is surrounded by fruit farms, pasture and some residential properties; there is minimal hunting on or around the lake.

Twenty-nine Trumpeter Swan carcasses were collected from Judson Lake between 29 February and 15 March 1992. In addition, three sick swans were captured and brought into a wildlife rehabilitation centre, where blood samples were collected before they died. Gross external and internal examination of 14 swans was conducted; seven were performed by a wildlife rehabilitator and seven were conducted by the Island Veterinary Hospital. Complete necroisies of 10 other swans were performed by the BCMAFF. The CWS measured lead residues in 12 liver and kidney samples, as well as three blood samples.

The prevalence of lead shot in sediment in Judson Lake, as well as in several other near-by areas where lead-poisoned swans also were recovered [Laxton Lake (49° 00', 122° 21') and in a tidal channel and

pond of Pitt Lake (49° 25', 122° 33')], was estimated from sediment cores collected 15 September to 15 October 1992. Between 40 and 75 cores were obtained from each waterbody. Cores were collected to either the hardpan or a maximum depth of 30 cm; core diameter was 12 cm. Cores were examined on site. Individual cores were placed in a three-gallon bucket, and water was continually added until most of the sediment and organic particles were in suspension. The majority of the slurry was drained and the remainder was poured through a United States of America standard testing sieve (mesh size 1.00 mm) that retained shot larger than size #7. This included all shot typically used for hunting ducks and geese (sizes #5 to #2, diameters 3.05-4.57 mm). Contents remaining in the pan were visually examined to detect shot. Lead and steel shot were distinguished by applying a magnet.

Results

Swan mortality

Between 1976 and 1994, 186 dead or injured Trumpeter Swans were found, including those from the Judson Lake die-off. Most swans (142/186, 76%)

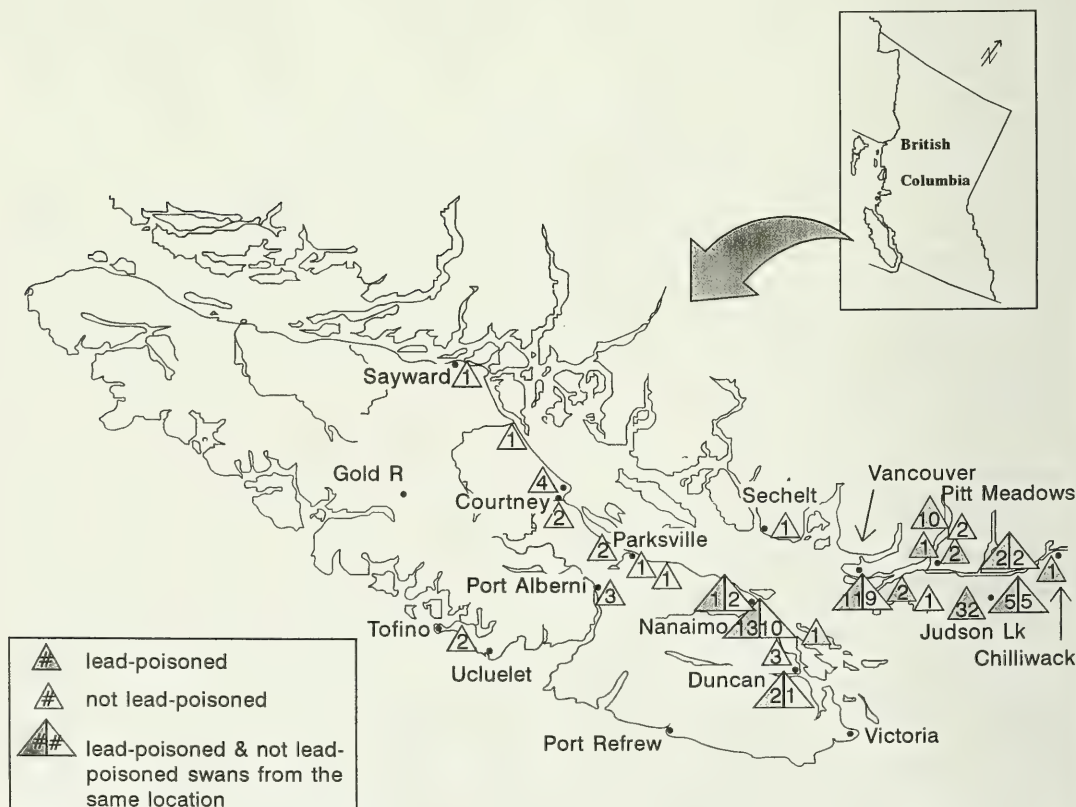


FIGURE 1. Location of reported Trumpeter Swans mortalities in south-east British Columbia, 1976-1994 (N = 142).

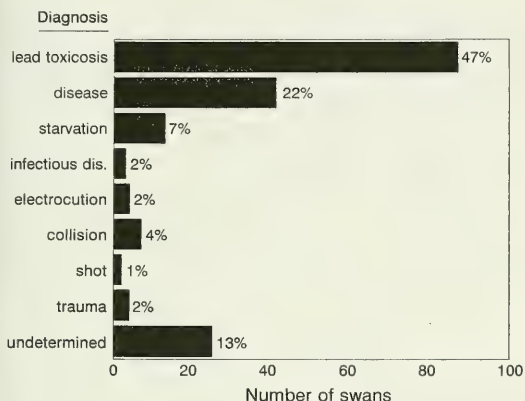


FIGURE 2. Cause of death in reported Trumpeter Swans mortalities in British Columbia, 1976-1994 (N=186). A detailed description of the diagnostic categories is provided in the Methods Section.

were from the lower Fraser valley and Vancouver Island (Figure 1). Of the 186 swans collected, 47% (87/186) were diagnosed as lead-poisoned (Figure 2). The majority of lead-poisoned swans were from the Lower Fraser Valley and southern Vancouver Island (83/87, 95%). Of the 44 swans collected outside the south-western coast of British Columbia, the only four classified as lead-poisoned were found

along the northern coast at Tlell River (53° 36'N, 131° 56'W), and Hunter Island (51° 57'N, 128° 00'W), and at Vanderhoof (54° 01'N, 124° 01'W). All lead-poisoned birds were found between November and May. Of the lead-poisoned birds which were aged and/or sexed, 71% (32/45) were adults and 58% (25/43) were females. Temporal trends in the incidence of lead poisoning were not observed (Figure 3).

Of 102 swans analyzed for lead; 65 (64%) were classified as lead-poisoned and one (1%) was sub-clinically exposed. Lead residues were measured in kidney of 75 Trumpeter Swans; 46 were classified as lead-poisoned, with a mean of 30.6 mg/g (SD 17.9, range 9.8-81 mg/g) (Table 1). Of the 75 swan livers analyzed for lead, 38 had levels diagnostic of lead poisoning, with a mean of 23.7 mg/g (SD 18.6, range 10-121 mg/g). When both were measured in the same bird, equal or higher lead levels were detected in kidney compared to liver tissues in the majority of the cases (55/62, 89%). Blood lead levels were determined in 20 swans, of which 14 had lead concentrations indicative of lead poisoning (mean 4.4, SD 2.9, range 1.4-10.5 mg/g). Seven of the 10 bone samples analyzed for lead had concentrations > 2 mg/g, the threshold value indicative of sub-lethal exposure (mean 18.3, SD 9.4, range 11.9-35.5 mg/g). Lead shot were detected in gizzards of 46 of the 62 lead-poisoned birds examined; the number of pellets per

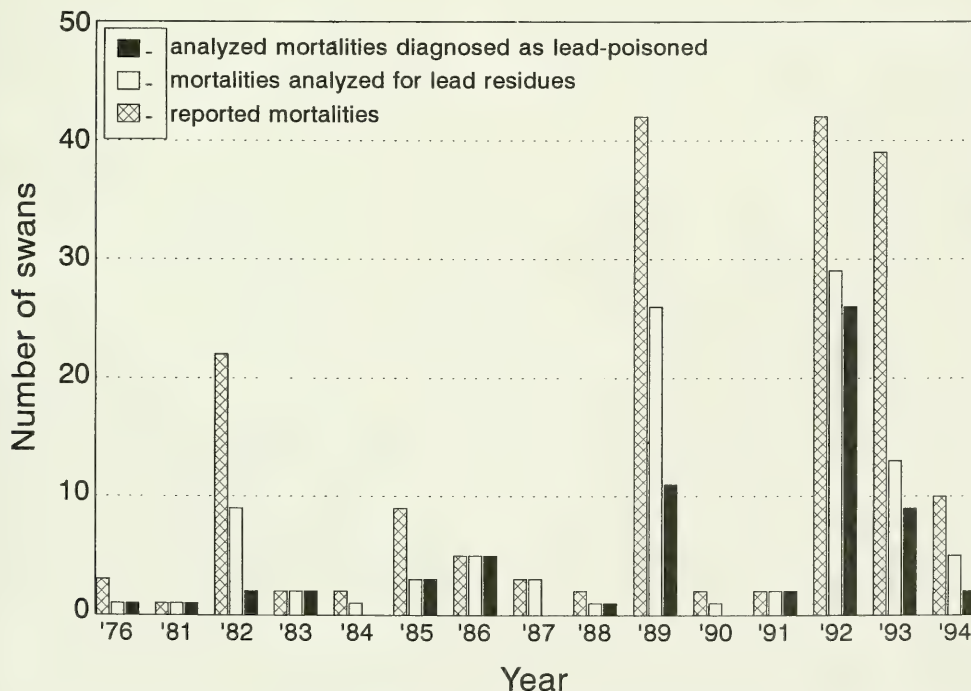


FIGURE 3. Reported annual mortality of Trumpeter Swans in British Columbia and the proportion of which were lead-poisoned, 1976-1994 (N = 186). Lead shot was banned in select waterfowl hunting areas in 1990.

TABLE 1. Lead concentrations (mg/g, wet weight) in tissues of Trumpeter Swans collected in British Columbia, 1976-1994 (N=102).

	Lead concentration (mg/g, wet weight)				Number of shot in gizzard	
	kidney	liver	blood	bone	lead	steel
Lead-poisoned birds						
mean	30.6	23.7	4.4	18.3 ^a	16.8	3.3
SD	17.9	18.6	2.9	9.4	17.3	3.2
n	47	38	14	7	34 ^b	9 ^c
(range)	(9.8-81)	(10-121)	(1.4-10.5)	(11.9-35.5)	(1-80)	(1-11)
Birds not exposed to toxicologically relevant lead levels ^d						
mean	0.9	1.0	0.05	0.35	—	—
SD	0.4	0.3	0.06	0	—	—
n	21	29	6	2	0	0
(range)	(ND ^e -4)	(ND-3)	(ND-0.16)	ND	—	—

^aBone of one swan contained 6.68 mg/g wet weight lead — an evaluated sub-clinical exposure (0.64 mg/g wet weight lead levels in kidney, no ingested lead noted in gizzard).

^bLead pellets detected in the gizzards of 46 of the 62 lead-poisoned swans examined; number of shot quantified in 34 of these 46 individuals.

^cSteel pellets detected in the gizzards of 18 of the 62 lead-poisoned swans examined; number of shot quantified in 9 of these 18 individuals.

^dFor concentrations below the lower limit of detection, calculations were completed using one half of the detection limit (DL) stated for the individual sample.

^eMinimum value of the DL is expressed as the average DL determined for those samples with lead levels below the DL: kidney = 1.8 mg/g; liver 1.9 mg/g; blood 0.01 mg/g; bone 0.7 mg/g.

gizzard were counted in 34 of these birds and ranged from 1 to 80, with an average of 16.8 (SD 17.3). Eighteen of the 62 examined lead-poisoned birds had steel shot in their gizzards; the number of pellets were counted in nine of the 18 birds and ranged from 1 to 11 with an average of 3.3 (SD 3.2). The amount of steel shot represented 21% (30/145) of the total shot found in the nine swans. All of the birds with steel shot in their gizzards were collected after 1992.

Judson Lake incident, 1992

Twenty-four of the 32 Trumpeter Swans that died at Judson Lake were necropsied and the cause of death attributed to lead poisoning from ingestion of lead shot. Of the eleven Trumpeter Swans sexed, nine were females. All eleven of the birds aged were adults. Gross necropsies revealed a moderate to marked reduction of muscle mass and fat reserves in all swans examined. Seven had little material in their digestive tracts. Each swan exhibited some conditions characteristic of lead poisoning which include esophageal impaction, proventricular expansion, bile in the intestinal tract, shrunken liver, accumulation of hemosiderin in the spleen and liver, absence of coronary fat, and an enlarged gall bladder filled with dark green, viscous bile (Longcore et al. 1974; Sanderson and Bellrose 1986; U.S. Fish and Wildlife Service 1986; Degernes and Redig 1988; A. J Erskine personal communication).

Seventeen kidneys and livers from the Judson Lake birds were analyzed for lead. Lead residues in kidneys from 16 swans were indicative of lead poi-

soning and one swan had kidney lead levels diagnostic of sub-clinical exposure. Concentrations ranged from 5 to 70.4 mg/g (mean 28.7 mg/g, SD 17.4 mg/g). Fourteen swans had liver lead levels which were classified as lead-poisoned and lead residues in livers of three swans reflected sub-clinical exposure with concentrations ranging from 6 to 48.8 mg/g (mean 18.6 mg/g, SD 11.6 mg/g). Lead levels were higher in kidney than liver in all but one case. The three swans from which blood samples were collected were classified as lead-poisoned; blood lead levels ranged from 2.8 to 4.4 mg/g (mean 3.5 mg/g, SD 0.81). Lead shot was detected in each of the 22 swans examined for shot. The number of pellets was counted in 17 of these birds and averaged 7.5 shot per bird (SD 4.9; range 1-17). The lead shot were mostly #4 or #5 pellet, which are often used in duck hunting. The shot were irregular in shape and generally had been eroded to the size of a #6 or smaller. Six steel shot were detected in the gizzards of four of the 12 swans examined (mean 1.5, SD 1.0, range 1-3 shot). The amount of steel shot represented 6.7% (6 of 90) of the total shot found in the 17 birds.

Lead shot were detected in all of the sediment samples collected from Judson Lake, Laxton Lake, and the Pitt Lake area. The number of pellets/m³ ranged from 37 to 177, with an average of 95.

Discussion

Swan mortality

Despite a ban on the use of lead shot for waterfowl hunting, there is recurring poisoning from

ingestion of lead shot by Trumpeter Swans wintering in south-western British Columbia. Between 1976 and 1994, almost half (87/186, 47%) of the dead or injured Trumpeter Swans reported to CWS were diagnosed as lead-poisoned. Our findings are comparable to percentages reported in other studies. Blus et al. (1989) reported a lead-poisoning rate of 62% (8 of 13) of Trumpeter Swan mortalities reported between 1979 and 1987 in Washington State. Their review indicated a lead-poisoning rate of 27% (23 of 84) of reported Trumpeter Swan fatalities from Skagit County, Washington between 1976 and 1986. McKelvey and MacNeill (1980) reported that 34% (57 of 166) of swans found dead in a combined necropsy study of Trumpeter and Tundra Swans from British Columbia exhibited gross lesions indicative of lead poisoning.

The majority of swan mortalities in British Columbia were reported during November to May from the Lower Fraser Valley and south-eastern Vancouver Island; these areas support large wintering populations of Trumpeter Swans (McKelvey et al. 1991; Boyd 1994). The large number of reported deaths may also be a consequence of these areas supporting dense human populations which may observe and report swan mortalities. The comparatively large number of cases reported between 1989 and 1992 (88/186, 47%) is a result of an increased monitoring effort by the Island Veterinary Hospital and Canadian Wildlife Service. The high incidence of lead poisoning among reported swan mortalities may also be biased. Bird afflicted with chronic lead poisoning are more likely to be brought into rehabilitation centres than other diseases that may kill more quickly and may kill larger numbers of birds.

Blus et al. (1989) were unable to correlate lead poisoning with the population decline of Trumpeter Swans breeding in the tri-state area of Idaho, Montana and Wyoming. The Trumpeter Swan population on the east coast of Vancouver Island increased from 646 birds in 1979 to 1415 swans in 1988 (Morrison 1988). In the Fraser River delta, peak mid-winter counts of swans principally Trumpeter Swans, increased steadily from 413 in 1987-88 to 730 in 1990-91 (Boyd 1994). During the 1970s and 1980s, Trumpeter Swan populations increased at an approximate growth rate of 7% per year, with most of the population growth attributed to a juvenile recruitment rate of about 20% minus a natural mortality rate of 5% (Boyd 1994). It is difficult to assess the impact of winter mortality resulting from lead poisoning on the population. However, the reproductive success, juvenile and adult survival and juvenile recruitment are greater than mortality from all causes throughout the year.

Judson Lake incident, 1992

Chronic lead poisoning occurs slowly as lead shot is eroded in the gizzard and lead is absorbed into the

bloodstream. Consequently, a bird could travel a considerable distance from the source of exposure before it became debilitated. Trumpeter Swans are usually absent from Judson Lake in the winter. Swans began to arrive in the area a month prior to the die-off, and lead pellets are completely eroded within 10-30 days in ducks (Bellrose 1959). Based on the partially eroded condition of some of the shot in their gizzards, the Trumpeter Swans probably did not ingest the shot prior to arriving in the area. Lead shot were detected in all of the sediment samples collected from Judson Lake, Laxton Lake, and the Pitt Lake area. Since 1976, all of the Trumpeter Swans analyzed for lead from the three lakes showed significant lead residues. Depending on the substrate, lead shot will continue to be available for many years, especially to species such as swans which forage deep into sediments. Lead poisoning of swans from ingestion of shot used almost two decades earlier has been documented in Ireland (O'Halloran et al. 1988).

Management Implications

Lead poisoning of Trumpeter Swans has occurred repeatedly in British Columbia since 1925. Between 1976 and 1994, lead poisoning was the most common cause of death in reported Trumpeter Swan mortalities in British Columbia. In those birds with signs of lead poisoning, lead shot were nearly always found. Following the United States initiative, in 1990 the Canadian federal and provincial governments restricted the use of lead shot in selected waterfowl hunting zones including important swan wintering areas. Further restrictions were implemented in 1993, when the use of lead shot for any purpose, including recreational activities such as clay-target shooting, was banned on specific dykes and foreshores in areas of intense waterfowl use in the Fraser Delta. However, this approach was deemed inadequate to protect raptors (for example, Bald Eagles) from secondary poisoning (Elliott et al. 1992) and, in British Columbia, a province-wide ban was in effect during the 1995 waterfowl hunting season. Starting in the 1997 hunting season, there will be a nation-wide ban on the use of lead shot for waterfowl hunting in Canada. Nevertheless, the incident at Judson Lake illustrates that, even with a lead shot ban, it is likely that swans wintering in some areas that support heavy hunting or clay-target shooting activities will continue to die from lead poisoning. Also, non-compliance with current regulations could be a continuing source of lead shot deposition. Waterfowl hunters may currently be carrying lead shot on the pretext of encountering upland game. There are limited management options available to further reduce the prevalence of lead poisoning in local swan populations. Options for remediating hot spots include the dredging of sediments to remove spent shot (generally not recommended

because of the adverse impacts on habitat) and provision of grit supplement to help reduce lead shot ingestion or reduce the toxicity of ingested shot, particularly in grit-poor organic sediments (likely a difficult proposition for trumpeter swans that usually forage deep in the sediment).

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Reproductive Effort and Survival of Wild Blue-winged Teal, *Anas discors*, with Backpack Harness and Implant Transmitters

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We compared nesting effort (proportion of females nesting), survival, and abandonment rates of female Blue-winged Teal (*Anas discors*) marked with backpack harness vs. surgically implanted transmitters. Nesting effort was measured by capturing pre-laying females, applying a backpack or implant radio, and using telemetry to locate nests. A significantly greater ($G = 7.66$, $P = 0.006$) proportion of implanted females (6 of 6) nested compared to backpack-marked females (3 of 8). We also compared effects of implant and backpack transmitters when given to females captured on the nest during laying or early incubation. Two of five nesting females given implants during laying then abandoned, whereas no females given backpacks ($n = 4$) abandoned. No difference was detected in daily survival rates of females with implants (0.9963) and backpacks (0.9931) ($F = 0.20$, $P = 0.66$).

Key Words: Blue-winged Teal, *Anas discors*, implant, radio, telemetry, transmitter.

Radio telemetry has been used to study wild birds for over 30 years. Telemetry is particularly useful for studies of habitat use and reproduction of dabbling ducks (*Anas* spp.) because females and broods are mobile and secretive. Telemetry equalizes the probability of detecting wildlife in different habitats, so it provides measures of habitat use that are not biased by vagaries of visual observation. Radio packages, however, may alter the behavior and reproductive performance of birds. Early studies on ducks revealed that the widely-used Dwyer (1972) harness caused feather wear, skin irritation, and altered behavior (Greenwood and Sargeant 1973; Gilmer et al. 1974), and was unsuitable for diving ducks (*Aythya* spp.: Perry 1981). There has been continued use of Dwyer backpacks due to the necessity of telemetry and, until recently, the lack of alternative radio designs (Pietz et al. 1995). Development of radios that may be surgically implanted in a duck's abdominal cavity (Olsen et al. 1992) made it possible to radio-mark diving ducks (Perry 1981; Korschgen et al. 1984; Sorenson 1989; Olsen et al. 1992). Implanted radios also have fewer detrimental effects on breeding Mallards (*Anas platyrhynchos*) than the traditional backpack design (Rotella et al. 1993; Pietz et al. 1993).

Comparisons of the effects of implant and backpack radios have largely focused on Mallards. For captive Blue-winged Teal, implant radios did not alter time budgets, whereas Dwyer backpacks clearly affected teal behavior (Garrettson 1996). Our objectives were threefold: (1) to compare nesting (proportion of females attempting at least one nest) and reneesting effort of wild, free-ranging female Blue-winged Teal marked prior to laying with Dwyer (1972) backpack radios or abdominal

implant radios; (2) to record abandonment rates of laying and incubating females captured on nests and given backpack or implant radios; and (3) to compare mortality rates of females with implant or backpack radios.

Study Area and Methods

We worked in the prairie parkland region of southwestern Manitoba, in the Odanah municipality (50°2'N, 99°42'W) during April–August 1993, on two 6.4-km² study sites. The area is dominated by small grain agriculture (Kiel et al. 1972), and has a high density of small wetlands.

Applying Backpack Radios

Ducks in the backpack treatment were fitted with a Dwyer backpack radio that weighed 15 g, measured $2.5 \times 1.8 \times 1.3$ cm, and had a 20 cm whip antenna. Dwyer (1972) backpack harnesses normally have two flexible body loops; one encircles the neck just in front of the keel, and the second loop encircles the body behind the wings. For this study, the two body loops were linked together on the bird's ventral side. This causes the front loop to be positioned on the duck's breast and allows for a looser attachment of the backpack. We fitted transmitters so that it was possible to fit two fingers (3 cm wide) between the duck and the radio. This modification caused fewer behavior changes in captive Mallards than did the traditional mount (F. C. Rohwer, unpublished data). Backpack and implant radios were manufactured by Advanced Telemetry Systems (Isanti, Minnesota).

Applying Implant Radios

Ducks in the implant treatment had radios surgically implanted into their abdominal cavities.

Implant radios were cylindrical, had a coiled antenna that was encased with other radio components in inert plastic, measured 3.3×1.5 cm, and weighed 15 g. We implanted radio transmitters in the abdominal cavities of Blue-winged Teal according to the methods of Olsen et al. (1992), except that we administered 4.0% isoflurane with oxygen (2-2.5 L/minute, 1.0 L/minute if administered with an endotracheal tube) to induce anesthesia, and 2.5% isoflurane to maintain a surgical plane. The transmitter was placed dorsally on the right side of the abdominal cavity, posterior to the liver. Surgeries were performed in a heated mobile trailer.

Pre-laying Females and Nesting Effort

We decoy-trapped (Sharp and Lokemoen 1987) 28 pre-laying Blue-winged Teal females from 5 May to 22 May. Each bird was weighed, measured (wing, tarsus and culmen), banded and fitted with a unique combination of nasal disks (Lokemoen and Sharp 1985). Females were alternately assigned to either a backpack ($n = 13$) or implant treatment ($n = 15$). We did not use a non-radioed control group because of the difficulty in relocating wild dabbling duck females without radios. Birds were released, along with any males in the trap, within one hour of trapping if given a backpack radio, and within two hours of trapping if given an implant radio.

We began radio-tracking Blue-winged Teal on 20 May 1993, using a vehicle-mounted null-peak telemetry system (Kenward 1987), and hand-held antennas. We attempted to locate females from 0630 to 1300 CDT (Gloutney et al. 1993). Females tracked to nesting cover were flushed to discover nests, whereupon we recorded clutch size and incubation stage (Weller 1956). We attempted to radio-locate all females at least every third day by telemetry. If a female was not at her nest, we checked the location to determine nest fate. If the nest was destroyed or abandoned, we continued radio-tracking the female to detect renesting. While radio-tracking, we attempted to observe females and determine pairing status without flushing them. Nest checks were performed when the female was absent from the nest. We attempted to locate missing birds from fixed-wing aircraft every 7-10 days.

Nesting Females and Nest Abandonment

Our second means for comparing backpack and implant radios was to apply radios to teal that had begun nesting. Captured females were either in the egg-laying stage or had incubated no more than two days, and were fitted with backpack ($n = 4$) or implant ($n = 6$) radios as described above. For most brood ecology studies, radios are applied to females late in incubation. We applied radios much earlier, to maximize disturbance to females and thus the possibility of detecting differences in abandonment by radio type, as we had data suggesting that Blue-winged Teal tolerated backpack radios well early in

nesting (F. C. Rohwer, unpublished data). We located nests by searching upland cover using a 0.7 cm thick chain pulled between two all-terrain vehicles (Higgins et al. 1969, 1977; Klett et al. 1986). We captured nesting females with a long-handled net, or with a nest trap (Weller 1957) if the initial netting attempt failed. We released backpack-marked birds at least 100 m from the nest site. We released implanted birds 10 m from the nest while they were still groggy from anesthesia, and observed them until they appeared recovered.

We interpreted absence of the female from the nest the morning after radio-marking, along with cold eggs in a nest that the hen had not revisited, as evidence of abandonment. Abandonment was confirmed on a second nest check.

Transmitter Range, Female Survival and Statistical Analyses

We continued tracking radio-marked birds, including females with broods, until they left the vicinity of the study areas, their radios failed, or we could not locate them by ground or air searches. We estimated the upper range of radio transmitters in the field on clear days by measuring the maximum distance from which a signal could be heard from a stationary female (usually a nesting bird). We obtained estimates for vehicle-mounted and hand-held antennas.

A one-way ANOVA, weighted by exposure days, was used to test for differences in survival of implanted and backpack-marked females. We calculated survival estimates based on birds marked during pre-laying and nesting, and included five birds marked with backpacks late in incubation for a study of brood ecology. Survival estimates are based on combined data for females during pre-laying, nesting and brood rearing. Three implanted birds that were never relocated were excluded from survival estimates. We used G tests (Zar 1984) to examine differences in nesting effort by implanted and backpack-marked females.

Results

Reproductive Parameters for Birds Marked During Pre-laying

Of birds tracked through 15 June, all six of the females with implants and three of eight of the females with backpacks nested ($G = 7.66$, $P = 0.006$). Average number of nest attempts (1st nests and renests) for birds tracked through 15 June was 1.2 ($SD = 0.41$, $n = 6$) for implanted birds and 0.5 ($SD = 0.76$, $n = 3$) for birds with backpacks.

Average nest initiation date was 3 June ($SD = 7.9$, $n = 6$) for implanted birds and 5 June ($SD = 6.4$, $n = 3$) for backpack-marked birds. We found nests when birds with implants had laid an average of 5.0 ($SD = 2.83$) eggs, and birds with backpacks had laid an average of 5.33 ($SD = 3.03$) eggs. Three of six implanted birds and all three backpack-marked birds

that nested lost nests to abandonment or predators. Of those birds, one with an implant and one with a backpack renested. Renesting interval was three days for the backpack-marked bird and five days for the implanted bird. Both renesting birds lost nests during laying, and likely continued laying in a new nest bowl.

Loss of Females Marked During Pre-laying from the Study Area

Nine of 15 implanted females and 5 of 13 backpack-marked females marked pre-laying were permanently missing from the study site prior to 15 June ($G = 3.7$, $p = 0.05$). We assume missing birds left the study site; we had no reason to suspect radio failure, but cannot rule it out. Significantly more ($G = 5.25$, $p = 0.02$) implanted females (5 of 9) left the study area prior to 1 June than did backpack-marked females (1 of 5). We were able to track backpack-marked females for a significantly longer ($p = 0.03$) period (58.6d, $SD = 27.0$, $n = 12$) than we could implanted females (34.3d, $SD = 25.7$, $n = 15$). Time spent on the study site was unrelated to the date birds were given radios for backpack-marked ($R^2 = 0.14$) and implanted ($R^2 = 0.12$) females, but one implanted female marked early (5 May) was never relocated. This female may have been still migrating and had not settled on the study area.

Abandonment Rates of Females Marked While Nesting

None of the nesting birds marked with backpacks ($n = 4$) abandoned. Three females were given backpacks on day one or two of incubation. One female radio-marked after laying her sixth egg laid one additional egg on each of two subsequent days before her nest was destroyed.

Two of six teal implanted with radios during laying and incubation abandoned nests. Another nest was preyed upon before we could determine whether the hen had abandoned. Birds that abandoned were fitted with radios at the end of laying, or at four days of incubation. Birds that did not abandon received radios at the 6 or 11-egg stage of laying, or at 1-2 days of incubation. The female implanted at the 6-egg stage attended her nest the following day, but did not lay an egg. Two days after receiving an implant radio, she laid another egg, completing a 7-egg clutch. This nest hatched and the female successfully reared the brood.

Female Survival Estimates and Transmitter Range

Daily survival rate [1-(mortalities/exposure days), Mayfield 1975] was 0.9931 ± 0.0056 , 95% C. I. for birds with backpacks, and 0.9963 ± 0.0052 , 95% C. I. for birds with implants ($F = 0.20$, $P = 0.66$, PROC GLM, SAS Institute 1990). Over a typical (90-day) breeding season, survival rates are $60.6 \pm 28.4\%$, 95% C. I. for females with backpacks and $72.7 \pm 27.7\%$ for females with implants.

We recorded mortalities for two of 18 birds with implants, one an apparent predation during nesting, the other of unknown cause, pre-laying. Six of 22 backpack-marked birds died. Five mortalities on backpack-marked hens were apparent predation, the other unknown; four mortalities occurred during nesting, one late in the season to a non-breeder, and one during pre-laying. All but two mortalities occurred after birds in the laying effort study had initiated nests, or after 15 June. We recorded 541 exposure days for females given implants, and 870 exposure days for females given backpacks. Small sample sizes reduced our power to detect statistical differences in survival.

Maximum range of implant transmitters tracked from the ground averaged 243 m ($SD = 83.7$ m, $n = 6$), whereas range for backpacks was 2398 m ($SD = 1158.9$ m, $n = 2$). Implant transmitter range was approximately 400 m when tracked from the air at an altitude of 200 m. Flying at higher altitudes did not improve implant transmitter range.

Discussion

Birds with implants produced twice as many nests per bird than did birds with backpacks. Implant radios appear to affect Blue-winged Teal nesting effort less than do backpack radios, as has been shown with Mallards (Rotella et al. 1993). Some Blue-winged Teal that received implanted radios during nesting abandoned nests, but we put radios on birds during laying or early incubation. Researchers studying brood ecology need to radio-mark ducks during late incubation, and would likely use implant radios at that part of the nesting cycle. That some Blue-winged Teal did not abandon even early stage nests suggests that implant radios may be satisfactory for marking most nesting teal; however, backpack radios were best for marking birds captured on the nest, as no backpack-marked females abandoned nests. We urge caution in extrapolating results for nesting Blue-winged Teal to other duck species, however, as Blue-winged Teal are known for their low propensity toward nest abandonment (Armstrong and Robertson 1988).

Despite data favoring the use of implant radios for marking pre-laying Blue-winged Teal, the limited range of implants is a problem. Limited implant range may have affected the results of this study. We had to fly weekly to locate implanted birds that remained on the study areas. Ground-based telemetry never failed to locate backpack-marked birds on the study area that were later discovered by aerial telemetry. Consequently, birds with backpacks were located with greater frequency than those with implants. The longer intervals between locations of implanted birds may have biased us toward finding nests of birds with backpacks. Some birds with implants may have remained on the study area, initi-

ated a nest but had the nest destroyed before we located the female. Thus, the true difference in nesting effort between backpack-marked and implanted birds may have been greater than detected. Regardless of the effect on this particular study, our experience suggested that researchers using implants for Blue-winged Teal or other small ducks be prepared to fly frequently to locate birds.

Our results also indicated potential problems with putting backpack or implant radios on pre-laying Blue-winged Teal. Only about half the birds marked during pre-laying were relocated on or near our study area, whereas higher proportions of similarly radiomarked pre-laying Mallards remained on study areas (Rotella et al. 1993; D. Howerter, personal communication). Perhaps Blue-winged Teal, which are less philopatric than Mallards, are more apt to move in response to disturbances during pre-laying. Unless estimates of nesting effort are essential, researchers will save considerable expense and effort by waiting and marking hens on nests. Implanted females were slightly more likely to have left the study area prior to 15 June than were backpack-marked females, but were significantly more likely to have left prior to 1 June. Perhaps the more intensive disturbance of surgery contributed to implanted females leaving very early in the season, although most implanted females that left remained on the study area for at least 10 days after marking.

Behavioral observations indicated that captive Mallards (Greenwood and Sargeant 1973) and Blue-winged Teal (Greenwood and Sargeant 1973; Garrettson 1996) with backpacks spend more time preening and less time in the water than non-radioed controls, and that wild Mallards with backpacks preen and rest more than non-radioed controls (Pietz et al. 1993). By contrast, time budgets of captive Blue-winged Teal marked with implants do not differ from those of unradioted controls (Garrettson 1996). We found higher survival for implanted females than for backpack-marked females, but this difference was not significant, consistent with results for brood-rearing wild Mallards (Dzus and Clark 1996). However, both studies had small sample sizes and could have only detected substantial differences in survival. A comparison of female survival with larger sample sizes would better determine effects of radio types on survival.

Low range, high cost, and the need for specialized equipment were the major disadvantages of implants. Implants are probably acceptable for use in larger ducks such as Canvasbacks (*Aythya valisineria*) or Mallards where larger packages with longer ranges can be used (Korschgen et al. 1984), or in situations where birds readily can be tracked from the air. Backpacks certainly appear to inhibit nesting attempts more than do implants, so implants may provide a more accurate estimate of nesting effort for

Blue-winged Teal. Improvements in implant transmitter range would help make them the preferred method for studying other aspects of Blue-winged Teal reproduction. Alternatively, an external radio package attached with a subcutaneous anchor and sutures (Pietz et al. 1995) may have fewer detrimental effects than backpack harness radios, but transmitter weights must be kept low to avoid problems with radio retention (Zimmer 1996), and Mallard hens given anchor transmitters during pre-laying had lower nesting effort and duckling survival than those given implants (Paquette et al. 1997).

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Range Extension and New Locality Records for the Stonecat, *Noturus flavus*, in Manitoba: Evidence for a Recent Natural Invasion

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McCulloch, Bruce R., and Kenneth W. Stewart. 1998. Range extension and new locality records for the Stonecat, *Noturus flavus*, in Manitoba: evidence for a recent natural invasion. *Canadian Field-Naturalist* 112 (2): 217–224.

Range extensions and new locality records for the Stonecat in Manitoba are given from the Red and Assiniboine rivers and their associated tributaries. Maximum potential dispersal in the Assiniboine, Little Saskatchewan, Souris, and Rat rivers has been realized due to the presence of dams. Absence of Stonecats upstream of these dams suggests that the records of the species in Manitoba in the 1920s are erroneous, and instead supports a more recent invasion coinciding with the first authenticated record in 1969. Collection records of the species from the United States portion of the Red River support the theory of natural invasion from the upper Mississippi River drainage to the headwaters of the Red River drainage at Lake Traverse during high spring meltwater conditions. Further range extensions in the Hudson Bay drainage may occur in Lake Winnipeg and the rivers flowing into it. This may be limited by the minimum water temperature at which Stonecats will spawn.

Key Words: Stonecat, *Noturus flavus*, Manitoba, Red River, Assiniboine River, invasion, dispersal, dams.

The Stonecat, *Noturus flavus*, (Figure 1) has the greatest longitudinal distribution of any of the twenty-five members of its genus (Lee et al. 1981), and in recent years first state and provincial records have been documented in Arkansas (Buchanan 1973), Colorado (Platania et al. 1986) and Saskatchewan (Royer and Anderson 1977). Range

extensions and new locality records also have been reported from Kansas (Layher and Wood 1986) and Kentucky (Warren et al. 1991). While Stonecats are commonly associated with riffle habitat (see Figure 2 for photograph of typical habitat), they can exhibit considerable environmental plasticity, occurring in western Lake Erie (Owen et al. 1981) and Lake

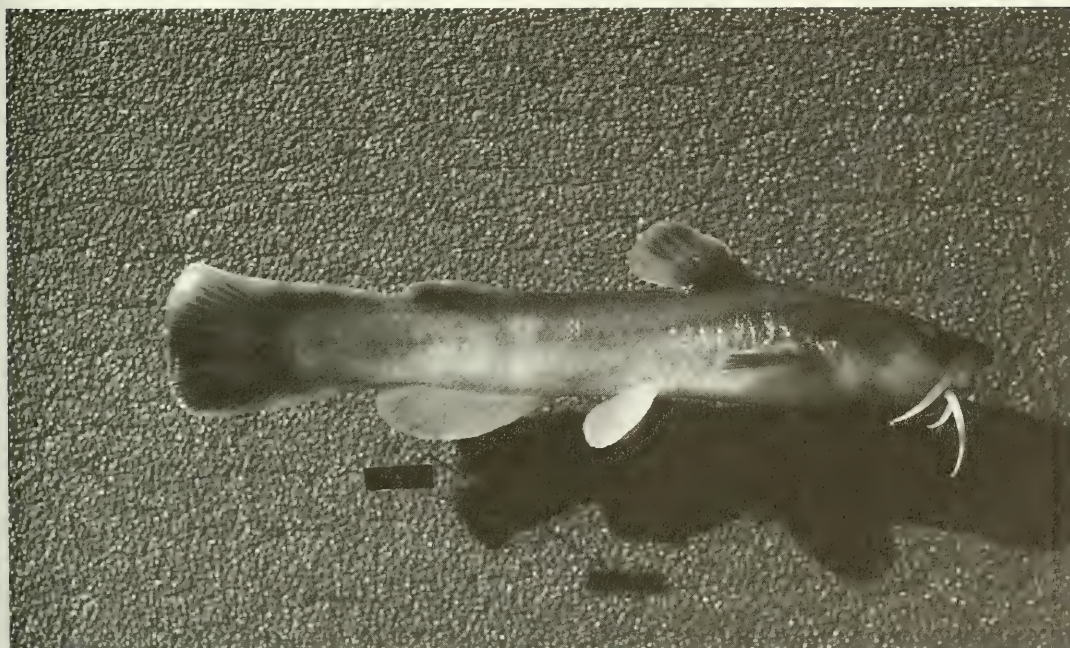


FIGURE 1. Photograph of Stonecat collected from the Little Saskatchewan River at Rivers, Manitoba (see site 19, Table 1).



FIGURE 2. Typical riffle habitat occupied by Stonecats in the Little Saskatchewan River at Rivers, Manitoba (see site 19, Table 1).

Huron in wave-exposed rocky areas (Trautman 1981), the mainstem of the Mississippi River (Robison and Buchanan 1985) and in the Canadian section of the Red River (Stewart and Lindsey 1970).

In Manitoba, the first authenticated collection of the Stonecat in the Hudson Bay drainage was made in 1969, with nine specimens taken from the Red River just south of Winnipeg (Stewart and Lindsey 1970). Those authors offered two hypotheses with respect to the timing of the invasion of the Stonecat into the drainage. The first was that the species moved into glacial Lake Agassiz while the latter was discharging via the Warren River outlet (now occupied by the Minnesota River); the second, that Stonecats moved into the watershed more recently from the Minnesota River. By 1983, the Stonecat had been reported in the Assiniboine River west to the city of Brandon (Stewart et al. 1985). Crossman (1991) considered its presence in Manitoba to be the result of either natural invasion or unintentional introduction.

In 1989 and 1990, extensive surveys of the Red and Assiniboine river watersheds were conducted to: (1) determine, as accurately as possible, the present distribution of the Stonecat in Manitoba; (2) estimate its time of arrival in the Hudson Bay drainage and postulate a probable route of entry; and (3) suggest possible avenues for future dispersal in the drainage.

Methods and Materials

Road-accessible collection sites were selected from a 1:500 000 scale section map produced by the Province of Manitoba, Surveys and Mapping Branch. Latitudes and longitudes were recorded for each site using the same map. A Smith-Root Model 12 Electrofisher was used to collect fish in shallow, riffle habitats. Voltage and pulse rate were varied as required to immobilize small fish effectively. The operator concentrated on fish which were immobilized in the immediate area of the anode paddle, while a netter followed approximately one metre downstream, scanning the surrounding area for stunned fish. Sampling was conducted during daylight hours. Due to the tendency of Stonecats to seek cover during the day (Robison and Buchanan 1988), rocks were lifted to free any individuals wedged in crevices. Gillnets were used when sampling in deeper stretches of the Red and Assiniboine Rivers.

All individuals of all species collected were anaesthetized with 2-phenoxyethanol prior to fixation in 10% formaldehyde. After one week, specimens were rinsed in water for two days and then preserved in 50% isopropyl alcohol. All individuals were then identified and counted. Otoliths, pectoral spines, and viscera were removed for destructive analysis for other studies; no whole Stonecat specimens were retained.

At each collection site, air and water temperatures were recorded with a Hach electronic thermometer.

Water depth was measured with a metre stick. Surface water velocity was estimated by averaging three trials of timing the drift of liquid malachite green dye for one metre downstream. Substrate type was also noted. Complete collection records for all species from the Assiniboine River drainage, including environmental data when available, are summarized in McCulloch and Franzin (1996).

Recent unpublished Stonecat collection records from the University of Manitoba were incorporated into this study and collection sites plotted on a map of southern Manitoba using Corel Draw software.

Results

Table 1 summarizes new collection records for Stonecats in Manitoba, and Figure 3 the presently known Stonecat distribution within the province. Previously known records from the Assiniboine River are summarized in Stewart et al. (1985), and are shown in Figure 3 as filled triangles. In the Assiniboine River, Stonecats were collected in five locations (sites 12-16) upstream of their previously known limit. The two individuals collected at the town of Shellmouth (site 16 in Figure 3) in 1990 represent the northernmost known occurrence of the

species in North America. This site was sampled in 1989 when there was a bridge crossing the river. Replacement of the bridge with a culvert the following year increased discharge downstream, creating riffle habitat close to shore. The area immediately below the Shellmouth Dam (5 river kilometres upstream from the town of Shellmouth) was sampled once in 1989 and once again in 1990, but failed to produce Stonecats. Construction of this dam was completed in 1969 producing Lake of the Prairies, a reservoir on the Assiniboine River. Substrate in the tailrace of the dam consists of large boulders, which, coupled with high water velocities, made effective sampling difficult. Sampling upstream of the Shellmouth Dam in both the Assiniboine and Shell rivers did not yield any Stonecats.

In the Little Saskatchewan River, Stonecats have been collected upstream to the town of Rivers in the uppermost riffle area below the Rivers Dam (site 19). This dam was constructed in 1960, creating Lake Wahtopanah, which has become one of southwestern Manitoba's largest sport fisheries (Gaboury et al. 1995). The first large riffle area upstream of the Rivers Dam was sampled weekly in the summer of 1990 (McCulloch and Stewart 1992), while the riffle

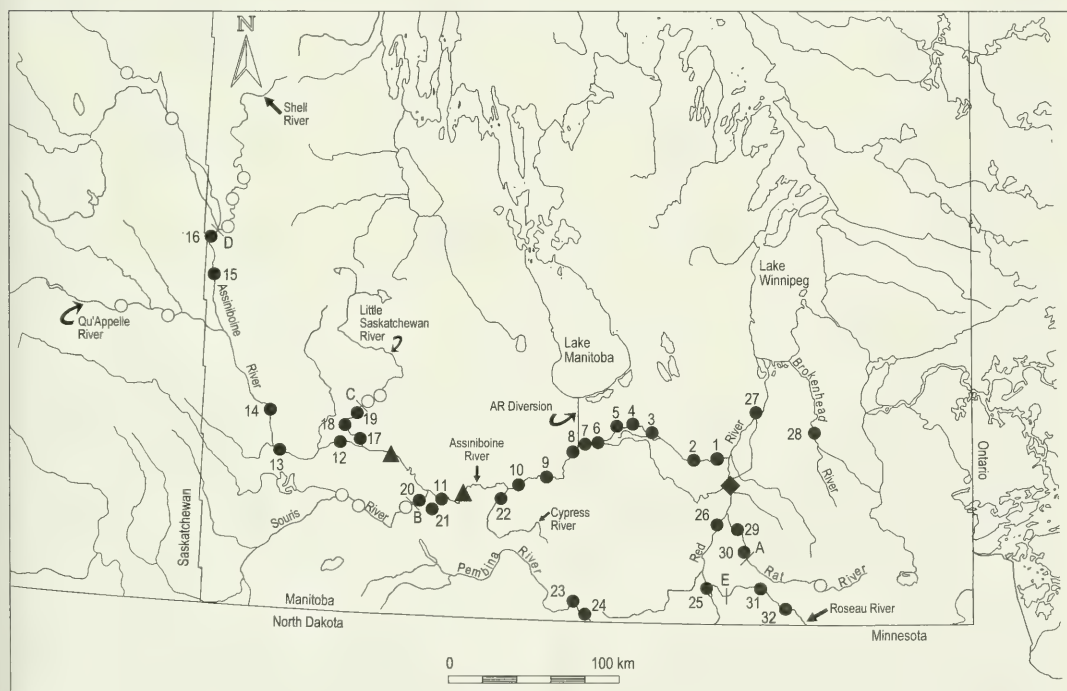


FIGURE 3. Collection locations for the Stonecat in Manitoba. Numbered filled circles correspond to numbers in Table 1. Filled triangles represent locations from Stewart et al. (1985). Filled diamond represents first authenticated Manitoba record (Stewart and Lindsey 1970). Letters represent dam locations (A: St. Malo Dam; B: Wawanesa Dam; C: Rivers Dam; D: Shellmouth Dam; E: Dominion City Dam). Open circles represent locations upstream of dams and in the Qu'Appelle River where Stonecats were absent from collections.

TABLE 1. New locality records for the Stonecat in Manitoba. Location numbers correspond to those in Figure 1. Date represents date of first collection at each location.

Location	Co-ordinates (N,W)	Date	# coll ¹	Collectors	C.C. ²
Assiniboine River					
1. Assiniboine Park, Winnipeg	49° 52', 97° 12'	27 June 1989	6	B. McCulloch, D. Tyson	a
2. W. Perimeter. Hwy, Winnipeg	49° 52', 97° 19'	15 May 1989	6	B. McCulloch, D. Tyson	c
3. Provincial Hwy 248	50° 01', 97° 45'	17 July 1989	3	B. McCulloch, D. Tyson	a
4. Provincial Hwy 26	50° 03', 97° 52'	17 July 1989	3	B. McCulloch, D. Tyson	a
5. Provincial Hwy 430	50° 02', 98° 01'	17 July 1989	1	B. McCulloch, D. Tyson	a
6. Campground @ Hwy 1	49° 58', 98° 05'	15 May 1989	8	B. McCulloch, D. Tyson	c
7. Portage Spillway	49° 57', 98° 18'	29 June 1990	7	B. McCulloch, D. Tyson	c
8. Provincial Hwy 305	49° 52', 98° 26'	20 June 1990	1	B. McCulloch, D. Tyson	c
9. Provincial Hwy 242	49° 45', 98° 38'	20 June 1990	3	B. McCulloch, D. Tyson	a
10. Provincial Hwy 34	49° 41', 98° 53'	15 May 1989	11	B. McCulloch, D. Tyson	c
11. W. of Provincial Hwy 340	49° 41', 99° 37'	28 August 1984	2	K. & J. Stewart, D. Pannu	a
12. Provincial Hwy 250	49° 54', 100° 18'	26 May 1989	4	B. McCulloch, D. Tyson	a
13. near Virden	49° 50', 100° 49'	04 July 1989	3	B. McCulloch, D. Tyson	a
14. Provincial Hwy 467	50° 05', 100° 55'	04 July 1989	5	B. McCulloch, D. Tyson	a
15. mouth of Conjuring Creek	50° 48', 101° 26'	05 July 1989	4	B. McCulloch, D. Tyson	a
16. Shellmouth	50° 56', 101° 29'	16 August 1990	2	B. McCulloch, D. Tyson	b
Little Saskatchewan River					
17. near mouth	49° 53', 100° 07'	04 July 1989	2	B. McCulloch, D. Tyson	a
18. Kirkham's Bridge	49° 55', 100° 09'	10 July 1990	9	B. McCulloch, D. Tyson	c
19. Rivers	50° 01', 100° 14'	19 July 1990	10	B. McCulloch, D. Tyson	c
Souris River					
20. Wawanesa	49° 36', 99° 41'	15 June 1989	5	B. McCulloch, D. Tyson	c
Oak Creek					
21. N of Provincial Hwy 340	49° 38', 99° 34'	28 August 1984	2	K. & J. Stewart, D. Pannu	c
Cypress River					
22. 3 km from mouth	49° 39', 98° 58'	11 June 1984	2	K. Dyke, H. Cavadias	b
Pembina River					
23. Provincial Hwy 31	49° 05', 98° 12'	17 September 1983	1	Biology of Fishes Class	b
24. Provincial Hwy 201	49° 01', 98° 12'	17 September 1983	1	Biology of Fishes Class	b
Red River					
25. Lettelier	49° 08', 97° 18'	June 1992	1	K. Stewart, J. Bayette	a
26. Ste. Agathe	49° 37', 97° 05'	24 August 1989	2	K. Stewart, B. McCulloch	a
27. Lockport	50° 05', 96° 56'	06 June 1982	1	K. Stewart	c
Brokenhead River					
28. E. of Beausejour	50° 04', 96° 29'	06 June 1984	5	R. Ratynski	b
Rat River					
29. Otterburne	49° 30', 97° 03'	23 May 1989	1	B. McCulloch, D. Tyson	a
30. St. Malo	49° 19', 96° 56'	1976	-	K. Stewart	b
Roseau River					
31. Provincial Hwy 59	49° 11', 96° 50'	18 September 1976	2	K. Stewart	c
32. near Stuartburn	49° 09', 96° 46'	11 July 1982	-	K. Stewart, K. Leavesley	c

¹denotes number of Stonecats collected²denotes Collection Code where a: single collection at site; b: multiple collections at site with Stonecats collected once; c: multiple collections at site with Stonecats collected several times.

area immediately below the Rapid City Dam was sampled every four hours for a 24-hour period in 1992 (McCulloch 1994). Stonecats were never collected at either site.

In the Souris River, five Stonecats were taken about fifty metres below the Wawanesa Dam (site 20

in Figure 3). The dam (B) was operational by 1952. No Stonecats have ever been collected upstream of this dam despite regular sampling. Road access is available a few kilometres upstream from the dam at Provincial Highway 2. This site has been sampled yearly in September by the Biology of Fishes class at

the University of Manitoba. Further upstream, where Provincial Highway 10 crosses the river, sampling was conducted weekly in the summer of 1989 (Horn 1993).

Presence of the Stonecat in Oak Creek (site 21), a tributary that enters the Souris River below the Wawanessa Dam, is evidence of the effectiveness of the dam as a barrier to upstream dispersal of the Stonecat. It also represents the smallest stream in Manitoba in which the species is known to occur. Oak Creek is unique in that twenty species have been collected from this creek, with up to sixteen species in a single collection (McCulloch and Franzin 1996).

Stonecat collection localities in the Assiniboine River tributaries and in the Assiniboine River west of Portage la Prairie are upstream of the Portage Spillway (sites 8-22). This spillway was completed in 1972 to control water flow during flood and non-flood conditions.

Stonecats were collected at two locations (sites 23 and 24) in the Pembina River in 1983. Drought-like conditions in the late 1980s reduced flow in the river, leaving intermittent pools in most areas below Swan Lake. Presence of the Stonecat in the Pembina River is suspect, and relies on adequate stream flow conditions (Stewart and McCulloch 1990). The river has been sampled several times at the Provincial Highway 31 crossing since the species was first recorded from there, with no Stonecats collected. Stonecats entered the Pembina River from the Red River. The Pembina River empties into the Red River three kilometres south of the Canada-United States border.

The presence of the Stonecat in the Brokenhead River (site 28) suggests the use of Lake Winnipeg as a dispersal route. To reach the Brokenhead River from the Red River, Stonecats would have to have migrated along 9.4 kilometres of Lake Winnipeg shoreline which separates the two river mouths (Stewart and McCulloch 1990). No Stonecats have been reported from Lake Winnipeg itself, despite numerous nearshore collections (Hanke 1996).

Stonecats were collected in the Rat River at the tailrace of the St. Malo Dam (site 30) in 1976 by one of us (Stewart). This dam was built in 1958. No Stonecats have been collected since then, although the site has been sampled several times.

In the Roseau River, Stonecats have been collected at Provincial Highway 59 and near the town of Stuartburn (sites 31 and 32), both of which are upstream of the former dam at Dominion City (E in Figure 3). Prior to 1992, this dam was overtopped by spring runoff in most years (Gaboury et al. 1995) due to its location in the flat Red River floodplain. Upstream access at water velocities which Stonecats could swim against was probably available regularly. In 1992, a pool and riffle fishway design was con-

structed to allow year-round fish passage (Gaboury et al. 1995).

Stonecats have been absent from Lake Manitoba collections made at Delta Marsh by students from the University of Manitoba. As such, it is the only one of the five ictalurid species found in Manitoba which has not entered the lake following the construction of the Assiniboine River Diversion in 1970 (Stewart et al. 1985). The diversion carries Assiniboine River water from near Portage la Prairie to the south end of Lake Manitoba during periods of high water levels.

Stonecats also were absent from collections made in the Qu'Appelle River in 1989. No physical barriers prevent dispersal in this river where collections were made in suitable habitat, and absence from collections remains unexplained.

Discussion

Collections made throughout the Red and Assiniboine River drainages suggest that Stonecats have dispersed as far as possible in the Souris, Assiniboine, Rat, and Little Saskatchewan Rivers. Distribution in these rivers is not likely to expand, unless introductions are made upstream of the dams on these rivers.

The Stonecat appears to have benefitted from river alterations, since many good Stonecat collection sites were at road crossings, where construction may have created Stonecat habitat by the addition of rocks and boulders to the riverbed. This was certainly evident in the Assiniboine River at Shellmouth, where Stonecats were collected only after a culvert had replaced a bridge, creating riffle areas. Stewart and Lindsey (1970) suggested that habitat alterations, such as river channel constriction and addition of boulder fill might serve to concentrate Stonecats, by creating suitable habitat where none existed previously.

The distribution of the Stonecat in Manitoba suggests a recent arrival into the Hudson Bay watershed. If the species had been a re-colonizer during deglaciation, it would certainly be present upstream of the dams on the Souris and Little Saskatchewan rivers and in the Shell and Assiniboine rivers upstream of the Shellmouth Dam. The presence of the Stonecat in the Roseau River upstream from the Dominion City Dam demonstrates that it will establish populations in suitable habitat above dams, given that access is possible. The deeper, more narrow, higher gradient and steep-walled valleys of rivers in the western part of the province, such as the Pembina and Souris, do not allow them to overspill their banks during flooding. Water velocities when these dams are overtopped by runoff are probably too great for Stonecats to pass (Stewart and McCulloch 1990).

While the distribution pattern of the Stonecat in Assiniboine River tributaries and in the Assiniboine River west of Portage la Prairie (upstream of the

Portage Spillway) supports a recent invasion, it implies that either Stonecats were present in the Assiniboine River upstream of the Assiniboine River Floodway Control Structure before it was constructed in 1972 or that Stonecats are capable of swimming through a 5-metre conduit in the spillway wall. It is unknown whether fish passage is possible through this opening due to high water velocities (Daniels, personal communication).

If the Stonecat has been a natural invader from the Mississippi River drainage, it must have traversed a temporary connection between the Minnesota River and Lake Traverse (Stewart and Lindsey 1970). Underhill (1957) stated that during high spring meltwater years temporary connections are made between these two water bodies. Smith (1986) stated that floodplains can function as river channels during high meltwater periods.

The initial dispersal of the Stonecat in the Hudson Bay drainage through the lentic habitat of Lake Traverse seems plausible for several reasons. Trautman (1981) has reported Stonecats in Lakes Erie and Huron in wave-exposed rocky habitats, while Scott and Crossman (1973) stated that Stonecats are found from the shore to a depth of 35 metres in the Great Lakes. Also, presence of the Stonecat in the Brokenhead River suggests entry from the Red River via Lake Winnipeg. While no Stonecats have been reported from Lake Winnipeg, it appears that Stonecats have used the lake as a dispersal route, if not for permanent occupation.

Absence of Stonecats above the dams on the Souris, Little Saskatchewan, and Assiniboine rivers does not support records of the species in Manitoba prior to its first authenticated record in 1969 (Stewart and Lindsey 1970), because, if they had been present before construction of these dams, they should occur above them today. Bissett (1927) and Bajkov (1928) claimed that Stonecats occurred in Manitoba, but gave no locality. From the 1969 record, it required a maximum of twenty years (1969 to 1989) for the Stonecat to disperse from the Red River nearly to the base of the Shellmouth Dam on the Assiniboine River. Given the records from the 1920s, and the dates of dam completion, presence of Stonecats above these dams would be expected had they actually been present then. Hubbs and Lagler (1967) refer to Stonecats from the Saskatchewan River, although no records exist for the species there. Taylor (1969) and Fedoruk (1969) both discount the pre-1969 Stonecat records as misidentifications, with the former suggesting the Red River records to be those of the Tadpole Madtom (*Noturus gyrinus*). Scott and Crossman (1973) stated that Stonecats are often mistaken for young-of-the-year Brown Bullheads, *Amerius nebulosus*. Stewart and McCulloch (1990) also stated that, since 1950, regular sampling of the Red and Assiniboine rivers has

been conducted by several agencies including the Royal Ontario Museum and the National Museum of Canada. No Stonecats were collected during these surveys.

The speculation by Crossman (1991) that Stonecats arrived in Manitoba through human actions is based mainly on the absence of the species in the United States portion of the Red River. However, Owen et al (1981) reported Stonecats from the Sheyenne River. Renard et al. (1986) reported two specimens from a section of the Red River which commences near the Wild Rose River mouth and encompasses 75 river kilometres, ending approximately 64 river kilometres upstream from East Grand Forks, North Dakota (Renard et al. 1986). This section of the river has a steep gradient and contains numerous riffles, which is similar to Stonecat habitat elsewhere in small to medium-sized rivers and streams (Becker 1983).

There is no evidence to suggest that Stonecats have been transported by anglers from the United States for use as a bait fish. However, Stewart et al. (1990*) reported consumption of a Stonecat by a Channel Catfish (*Ictalurus punctatus*) from the Assiniboine River at Brandon. The Red River north of Winnipeg supports one of the largest Channel Catfish sport fisheries in North America.

While the Stonecat's distribution in the United States portion of the Red River seems rare and discontinuous relative to Manitoba, this might be a result of sampling biases. Renard et al. (1986) employed electrofishing. While this will yield Stonecats from riffle areas, it is ineffective when sampling deep turbid stretches, which characterize most of the Red River. Collecting techniques used in the 1989 and 1990 surveys also suggest that some Stonecats will be missed if rocks are not lifted to free wedged individuals (Stewart and McCulloch 1990). Peterka (1993 personal communication) speculated that Stonecats have been present but overlooked in the United States portion of the Red River for a long time.

While potential future dispersal by the Stonecat is limited, some routes do exist. Stonecats have dispersed a significant distance in the Assiniboine River upstream from the mouth of the Qu'Appelle River. While collections made near the mouth of the Qu'Appelle at St. Lazare and further upstream in Saskatchewan yielded no Stonecats (Figure 1), there is potential for dispersal in this river. The ability of Stonecats to disperse into tributaries is evident from its Manitoba distribution. Suitable habitat exists in the Qu'Appelle River, and collection of the species there might be achieved through more intensive sampling. In 1989, each site in the Qu'Appelle River was sampled only once.

*See Documents Cited section.

The channelized nature of the Assiniboine River Diversion may have prevented Stonecats from entering Lake Manitoba. Scarnecchia (1988) suggested that Stonecats and other less streamlined species would not occupy channelized portions of prairie streams. The Assiniboine River floodway has many characteristics of such a channelized stream. However, Stewart and McCulloch (1990) suggested that, because the floodway is utilized only when diversion of water is needed, flow would be sporadic, with large pulses of water being released over short times. Any fish entering the floodway is likely to be passively swept into Lake Manitoba by floodwater, a process independent of habitat preferences (Stewart and McCulloch 1990).

If Lake Winnipeg can be utilized by Stonecats, the species might show up there and in major rivers running into the lake. However, its possible future distribution in the Winnipeg River, barring introduction, will be limited upstream to the base of the dam at Pine Falls.

One limitation likely to be placed on further Stonecat dispersal will be water temperature. Spawning has been observed at 23°C in the Assiniboine River (Stewart and McCulloch 1990) and Little Saskatchewan River (McCulloch and Stewart 1992), reducing the lowest previously recorded spawning temperature (Walsh and Burr 1985) by 2°C. Ultimately, establishment of more northerly populations will depend on the minimum water temperature in which Stonecats will spawn.

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Inspection of Snakes by White-breasted, *Sitta carolinensis*, and Pygmy, *Sitta pygmaea*, Nuthatches

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Bryan, J. E. 1998. Inspection of snakes by White-breasted, *Sitta carolinensis*, and Pygmy, *S. pygmaea*, nuthatches. Canadian Field-Naturalist 112(2): 225-229.

White-breasted (*Sitta carolinensis*) and Pygmy (*S. pygmaea*) nuthatches flew inspection flights around a live rattlesnake (*Crotalus viridis*) partly hidden beside a pond where the nuthatches came to drink. An experiment established that both nuthatch species inspected more frequently when model snakes were placed in the same location than when novel objects or no objects were present. Both species inspected snake models whether realistic or crude. Pygmy Nuthatches usually inspected while flying whereas White-breasted Nuthatches also inspected while hopping on the ground.

Key Words: White-breasted Nuthatch, *Sitta carolinensis*, Pygmy Nuthatch, *Sitta pygmaea*, snake inspection, snake defence, predator avoidance.

Several species of birds that are occasionally eaten by snakes recognize snakes and defend themselves or their offspring from them. The following birds have all been shown to respond to live snakes with defensive behaviour: woodpeckers (*Dryocopus pileatus*, *Picoides borealis*), Veery (*Catharus fuscescens*), warbler (*Dendroica magnolia*), flycatcher (*Empidonax minimus*), Bobolink (*Dolichonyx oryzivorus*), American Robin (*Turdus migratorius*), Gray Catbird (*Dumetella carolinensis*), Brown Thrasher (*Toxostoma rufum*), White-crowned Sparrow (*Zonotrichia leucophrys*), and swallows (*Hirundo pyrrhonota*, *Tachycineta bicolor*), [Nolan 1959; Annan 1961; Jackson 1974; Pettingill 1976; Gottfried 1979; James et al. 1983; Brown and Brown 1987; Winkler 1991, 1992]. Ring-billed Gull (*Larus delawarensis*) and Cock-of-the-Rock (*Rupicola rupicola*) do not behave defensively against snakes, possibly because they are less subject to snake predation (Fetterolf 1979; Trail 1987). The Blacksmith Plover (*Vanellus armatus*) behaves defensively against snakes, whereas its congener the Long-toed Lapwing (*V. crassirostris*) does not (Walters 1990).

Most previous observations of birds defending against snakes have been in the context of defending their nests from predation. The intensity of nest defence varied during the nesting cycle (Verbeek 1972; Gottfried 1979; Buitron 1983; James et al. 1983; Walters 1990; Neudorf and Sealy 1992; Bazin and Sealy 1993; Gill and Sealy 1996), presumably in relation to the bird's assessment of risk. Intensity of nest defence differs depending upon distance of potential predator from the nest (Gill et al. 1997), and there may be a threshold distance from the nest beyond which birds do not defend against predators (Winkler 1992). The experiment in this study was

conducted after the nesting season and well away from nest sites.

I watched a White-breasted (*Sitta carolinensis*) and several Pygmy (*S. pygmaea*) nuthatches hover while inspecting a live Western Rattlesnake (*Crotalus viridis*) partly hidden under a rock beside a pool where the birds often came to drink. Were the birds inspecting the object because it was a snake, or were they merely inspecting an unfamiliar object in a familiar location? The experiment described in this paper was performed to find out why the nuthatches responded to the snake.

Materials and Methods

This experiment was conducted in the Okanagan Valley near Penticton, British Columbia (49° 30'; 119° 38'). The site is in the rain-shadow of the Cascade Mountains at an elevation of 650 m. The habitat was Ponderosa Pine (*Pinus ponderosa*) parkland adjacent to the pool and my house. The experiment was conducted 8-14 August 1992 when the weather was hot and mainly dry (the median of the daily temperature ranges was 14-30°C). There were few natural sources of drinking water for the birds nearby, so many birds visited the pool.

The pool had an irregular shape approximately 2 by 3.5 m. The pool was accessible to the birds from the north or east side as the south was blocked by my house and the west by my garage. Bushes provided perches on the north side of the pool as did a tree on the east. Most birds perched on the bushes before flying down to drink at the pool. To observe the birds, I sat on the south side near my house where I was inconspicuous but not hidden.

The experiment consisted of placing a model of either a snake or an unfamiliar object on top of the

rock beside the pool where the rattlesnake had been from 21 to 31 July 1992. This position was on the north side of the pool where most birds flew by on their way to drink. The snake models were either a realistic plasticine model of a Night Snake (*Hypsiglena torquata*, Figure 1) or one of several crude models. The Night Snake is among the rarest of snakes in British Columbia, and Penticton is the northern limit of its range (Gregory and Campbell 1984). It is a small snake with light brown splotches on a tan background. This snake has far less contrast in colour than a Western Rattlesnake or the more-arboreal Gopher Snake (*Pituophis melanoleucus*). The model night snake was used because it was the only realistic model readily available. It was smaller in diameter (ca 1 cm) and shorter (42 cm) than the live rattlesnake (ca 3 and 80 cm, respectively). When being inspected by the nuthatches, the live snake was coiled and motionless with only its head and about 20% of its body visible from directly above.

The crude model was usually a rope of the same size and serpentine shape as the night snake, but the colour and markings were varied to reduce habituation by the birds (Figure 1). In different trials, the crude model was white (trials 1-3), red (trial 4), white with black stripes (trial 5), or a green rubber toy snake with a head and white and yellow blotches (trial 6). The unfamiliar objects used were usually golf balls, white (trials 1-3) or painted red (trials 4 and 5) to reduce habituation. Although there were no marked birds, it seems likely that many of the same individuals returned to the pool repeatedly. Repeated observation of the same individuals and habituation would make it more difficult to show inspection of snakes that is statistically significant. For the last trial, a block (4×4×11 cm) of wood with black stripes was substituted for the golf ball. All models were mounted on small pieces of plywood (8×14 cm).

TABLE 1. Numbers of nuthatches that did or did not inspect near the pool.

SPECIES	Inspect DID	Model DID NOT	Chi Square	P<
White-breasted Nuthatch				
Realistic snake	9	10		
Crude snake	7	13		
No model	0	13		
Novel object	1	10		
No model + novel object	1	23		
Realistic + crude snake	16	23	8.46	0.005
Pygmy Nuthatch				
Realistic snake	31	26		
Crude snake	30	31		
No model	12	59		
Novel object	12	41		
No model + novel object	24	100		
Realistic + crude snake	61	57	26.4	0.001

The models were put out in the same order for six trials: no model, novel object, crude snake, and realistic snake. I used a fixed order of presentation of model objects because my preliminary observation had established that a live snake was sufficient to elicit inspection behaviour. A trial with one model was terminated after at least one White-breasted or Pygmy nuthatch had visited the pool. The duration of a trial averaged 53 min (range: 20-300). Models were put out or removed when no nuthatches were near the pool.

The experiment consisted of placing snake models or unusual novel objects (Figure 1) near the corner of the pool nearest the forest where the rattlesnake had been and where the birds usually passed on their way to drink at the pool. The operational definition of inspection was that a bird altered its movement in response to the model and looked at the model object. Inspections occurred when birds flew, hopped, or perched. The total numbers of inspections or arrivals without inspection were counted for each trial.

White-breasted Nuthatches usually arrived one at a time, so behaviours were for different individuals within a trial. Pygmy Nuthatches, however, usually arrived in groups and I could not always distinguish among individuals that arrived simultaneously. For simultaneous arrivals, data were tallied by counting whether or not any individual inspected, which ensured independence. The numbers of individuals that did or did not inspect were pooled for all six trials and analyzed with chi-square (Siegel 1956). The average weight of White-breasted Nuthatches (21.1 g) is greater than for Pygmy Nuthatches (10.6 g) [Dunning 1993].

Results

When White-breasted or Pygmy nuthatches visited the pool when snake models were present, they inspected the snake models on 41% and 52% of visits (Table 1). In aerial inspections, a bird flew over the object and pool while often turning 180° close to the object before landing on a perch. Sometimes a bird circled the object several times or hovered above it while looking at it. Some birds turned toward the model while hopping on the ground. Occasionally, they turned their heads to look at it, and in a few instances they jumped up or backwards suddenly when the model came into their view. Other inspections were made while they perched close to the model and looked at it for about 15 s or longer.

The nuthatches also inspected models of unfamiliar objects. Indeed, Pygmy Nuthatches sometimes flew over the pool as though inspecting when there was no model object present at all (17%); these events were tallied as inspections because the birds circled the pool and the location where models were placed before landing to drink. White-breasted Nuthatches never inspected when no model was present; instead they flew or hopped directly to the

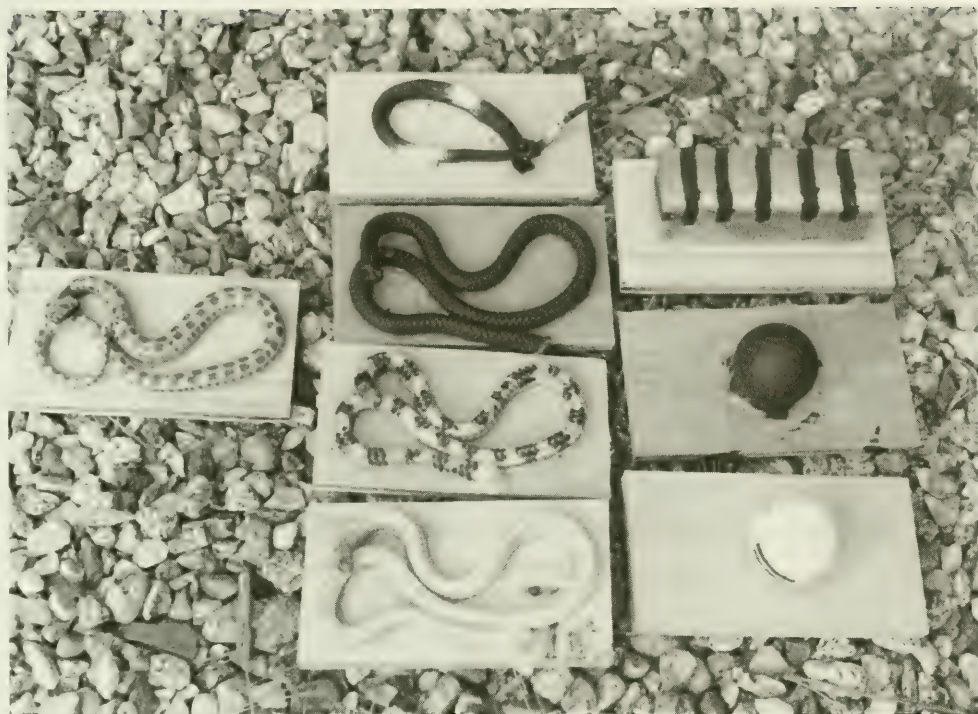


FIGURE 1. The models used in the experiment, left to right: realistic snake model, the crude snake models, and the novel objects.

pool to drink. Table 1 shows that both species inspected snake models more frequently than novel objects or no model when data for crude and realistic snakes are pooled and compared with no model and novel objects. For Pygmy Nuthatches all individual comparisons between each snake model and each control are also statistically significant (chi squares 7.5–18.3, $p < 0.01$), whereas for White-breasted Nuthatches all differences are in the same direction, but only the comparisons between realistic or crude snake models with no model are statistically significant (chi squares 3.9–6.4, $p < 0.05$).

The usual type of inspection differed for the two species. Pygmy Nuthatches usually inspected while flying (89%), whereas White-breasted Nuthatches most often inspected while hopping (57%). When approaching the pond, other birds of similar or smaller size moved away from White-breasted Nuthatches. Pygmy Nuthatches, however, were the smallest species visiting the pond and only displaced other Pygmy Nuthatches. Both species drank from the pool when the live snake or snake models were present. No bird directed aggressive behaviour toward any model.

Both species inspected the snakes less frequently in later trials with snake models than in earlier trials (Figure 2). For Pygmy Nuthatches, there was the

same pattern of decreasing inspection of novel objects, although only 12 birds inspected.

Other bird species occasionally drank from the pool when snake models were present but they inspected the models infrequently or not at all. No Evening Grosbeaks (*Coccothraustes vespertinus*) inspected snake models ($n = 36$ visits). Red-breasted Nuthatches (*Sitta canadensis*) rarely inspected snake models (3 of 29). Mountain Chickadees (*Parus gambeli*) sometimes inspected snake models (14 of 48), but little more frequently than they inspected novel objects (3 of 17, chi square = 0.4, ns).

Discussion

Pygmy Nuthatches inspected snake models more frequently than they did an unfamiliar new object. Presumably they did so because they recognized snakes as potential predators. Young Pygmy Nuthatches in the Okanagan Valley have been eaten by Gopher Snakes (Cannings et al. 1987). Pygmy Nuthatches build nests in tree cavities or nest boxes that are often near the ground (0.8–21.5 m, mean 6.6 m). Such nests could be reached by snakes, particularly Gopher Snakes that are good climbers (Thompson and Turner 1980).

White-breasted Nuthatches also inspected snake models more frequently than an unfamiliar new

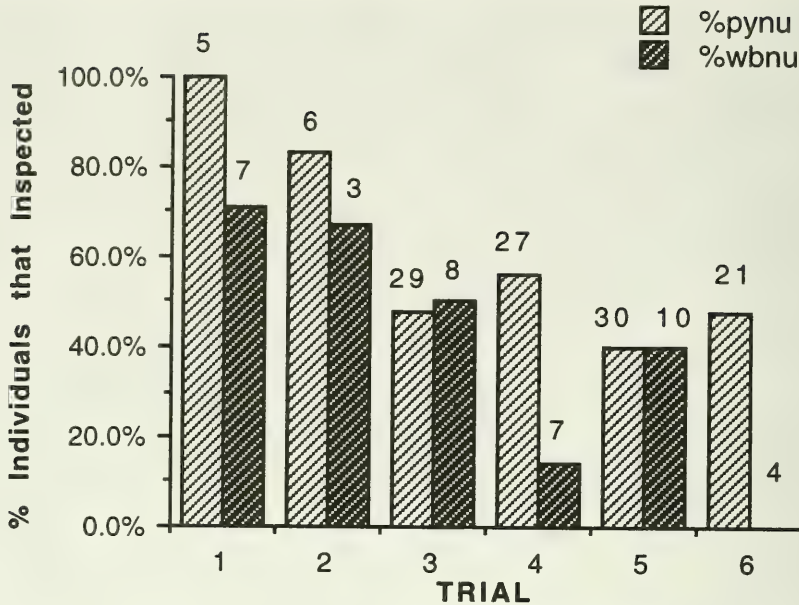


FIGURE 2. Decreasing inspection of realistic or crude snake models by Pygmy (pynu) and White-breasted nuthatches (wbnu). The data are birds inspecting once or more as a percentage of those visiting the pool during a trial (above each bar).

object in a familiar location. Like Pygmy Nuthatches, they nest in tree cavities, at the same height as Pygmy Nuthatches (1.5–21 m, mean 5.8 m; Cannings et al. 1987). I could not find any instances of snake predation documented for White-breasted Nuthatches.

The two species inspected models differently, possibly because of their great difference in size. The small, Pygmy Nuthatches performed more aerial inspections, even when there was no model to inspect. Presumably they flew such circles before landing beside the pool to look for larger birds that might chase them away. White-breasted Nuthatches usually landed north of the pool and hopped over to it, inspecting as they hopped. As described earlier, White-breasted Nuthatches are considerably larger and have longer legs which enable them to more effectively hop and displace other birds. White-breasted Nuthatches did not inspect when no model was present, but there was less need for them to look for other birds before landing, as smaller birds moved away from them.

Presumably, the same individuals returned to the pool day after day, hence, they soon became habituated to snake models. As described earlier, the crude models and novel objects were varied somewhat to overcome habituation. Although this may have reduced habituation, it did not eliminate it. Indeed, the nuthatches studied in this experiment habituated in the classical manner described by Thorpe (1963,

pages 338–342). When snake models were placed near nests, there also was habituation, as both species inspected the snake model on their first encounter but usually not on their next one (Bryan, in press).

The nuthatches did not give threat displays, alarm calls, or attack snake models, but other bird species sometimes do (Walters 1990; Winkler 1992; Nolan 1959; Gottfried 1979; James et al. 1983; Brown and Brown 1987). White-breasted Nuthatches give several threat displays in response to avian and mammalian predators (Kilham 1968). As mentioned above, the intensity of defence increases with proximity of predator to a nest site and varies with stage of nesting cycle. Consequently, inspection of snakes may have been the most appropriate response near the pool. Indeed, White-breasted Nuthatches responded with threat displays and alarm calls as well as inspections when snake models were placed near their nest sites (Long 1982; Bryan, in press). When Pygmy Nuthatches were similarly tested, they only inspected.

The risk of snake predation to adult nuthatches that fly well and spend little time on the ground seems low, although snakes do kill adult birds (Blem 1979; Terres 1980; Thompson and Turner 1980; Trail 1987). Indeed, rattlesnakes have specialized behaviour for capturing adult birds (Fitch and Twining 1946). They do not release birds from their fangs until death, whereas they immediately release rodents that other-

wise might bite back. Recognizing snakes as potential predators could allow adult birds to avoid snakes and thereby decrease their risk from predation.

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Occurrence and Abundance of Chiggers (Acari: Trombiculidae) on Bats (Chiroptera: Vespertilionidae) in Eastern Ontario

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Jones, Jason. 1998. Occurrence and abundance of chiggers (Acari: Trombiculidae) on bats (Chiroptera: Vespertilionidae) in eastern Ontario. *Canadian Field-Naturalist* 112(2): 230–233.

At four sites in eastern Ontario, the wings, ears and tragi of 33 of 366 bats harboured chiggers (larval trombiculids), *Leptotrombidium myotis* (Acari: Trombiculidae). These bats included 13 of 17 Big Brown Bats, *Eptesicus fuscus*, 6 of 9 Leib's Bats, *Myotis leibii*, 13 of 309 Little Brown Myotis, *M. lucifugus*, 1 of 30 Northern Myotis, *M. septentrionalis*, and 0 of 1 Eastern Pipistrelle, *Pipistrellus subflavus*. This study documents the first record of *L. myotis* on *M. leibii*. Levels of parasitism in *E. fuscus* were significantly higher, and in *M. lucifugus* significantly lower, when compared to conspecifics captured in Indiana (Whitaker 1973). In eastern Ontario, parasitized female *E. fuscus* experienced significantly higher infestation intensities than parasitized males and male *M. lucifugus* were parasitized significantly more often than females. Intensity of infestation may be linked to day roosts, and the presence and abundance of chiggers may be influenced by roost selection.

Key Words: Big Brown Bat, *Eptesicus fuscus*, chiggers, trombiculids, *Leptotrombidium myotis*, Leib's Bats, *Myotis leibii*, Little Brown Bats, *Myotis lucifugus*, Northern Myotis, *Myotis septentrionalis*, Eastern Pipistrelle, *Pipistrellus subflavus*, ectoparasites, Indiana, Ontario.

Most mammals host many species of arthropod endo- and ectoparasites (Marshall 1981). For example, specimens of 55 mammalian species from Indiana, USA, are known to host at least one species of ectoparasite and a total of 243 species of ectoparasites have been found on these 55 species (Whitaker 1982, 1991). This level of parasitism appears to be comparable to that measured in other mammals (Kim and Adler 1985). At low levels of infestation, parasites usually cause little harm to their hosts (Kim 1985). Heavy infestations, however, can cause severe effects including impairment of respiration (Kim et al. 1980), skin irritation and dermatitis (Nelson et al. 1977; Marshall 1981), and tissue degradation (Harwood and James 1979). Indirect effects include sleep deprivation due to irritation (Nelson et al. 1977), alteration of host nutritional intake (Good 1981), and reduction of host reproductive potential (May 1983). Not surprisingly, ectoparasite infestations can affect mammals' use of shelters and dens (e.g., Butler and Roper 1996; Lewis 1995).

Bats often host the parasitic larvae of trombiculid mites (Acari: Trombiculidae) commonly known as chiggers (e.g., Whitaker 1973; Kim and Adler 1985). These larvae are obligate parasites (Nutting 1985) and the species that parasitize bats usually attach to the skin (most commonly on the ear) by a feeding tube, the stylotome (Cross 1964). Chiggers are easily observable with the naked eye, often orange in colour, on the surface of the skin. Some species of chiggers even inhabit the nasal passages of their hosts (Natchatram 1970; Timm and Clauson 1985). Adult trombiculids are free-living predators

that live in a variety of habitats, including bat caves (McDaniel 1979). While some workers on the ecology and life history characteristics of bats in eastern Canada have discussed parasites (e.g. Fenton 1970) in general terms, this study is the first to document directly the presence and abundance of trombiculid ectoparasites on bats in the region.

Study Area and Methods

From 8 to 14 August 1996 between 2000 and 0100 h, bats were captured, using a double frame trap (Tuttle 1974), while swarming at abandoned mines near Eel Bay (44°27' N; 76°32' W) and Renfrew (45°22' N; 77°08' W), Tyendinaga Cave near Belleville (44°15' N; 77°16' W), and at a nursery colony in an old farmhouse near Westport (44°41' N; 76°24' W), in eastern Ontario. For the purposes of this paper, the bats captured at the Eel Bay and Westport sites have been lumped.

For each bat, species, sex, age, weight (to the nearest 0.1 g), forearm length (to the nearest mm), and presence and abundance of chiggers on the ears and wings were recorded. Chiggers were not found on other body areas. They were counted under a 20 × magnifying lens. From the ears of six bats [2 of *Eptesicus fuscus* (Palisot de Beauvois), 2 of *Myotis leibii* (Audubon and Bachman), and 2 of *M. lucifugus* (Le Conte)] chiggers were collected and sent to John O. Whitaker, Jr., at Indiana State University, for identification.

Results and Discussion

A total of 981 chiggers was found on 9% of 366 bats I examined (Table 1), including *E. fuscus*, *M.*

TABLE 1. Occurrence and abundance of chiggers on four different bat species in Eastern Ontario and Indiana. Males and females are combined for each species.

	Eel Bay ¹ +	Renfrew ¹	Tyendinaga ¹	All Ontario Sites ^{1,2}	Indiana ³
<i>Eptesicus fuscus</i>					
% of all captured bats (number captured)	15.2 (5)	4.0 (12)	0.0	4.6 (17)	na
% parasitism (number infested)	100.0 (5)	66.7 (8)	0.0	76.5 (13)	2.4 (12)
number of chiggers/ captured bat	28.2	6.7	0.0	13.0	0.1
number of chiggers/ parasitized bat	28.2	10.0	0.0	17.0	3.8
<i>Myotis leibii</i>					
% of all captured bats (number captured)	12.1 (4)	1.7 (5)	0.0	2.5 (9)	na
% parasitism (number infested)	100.0 (4)	40.0 (2)	0.0	66.7 (6)	na
number of chiggers/ captured bat	19.5	17.6	0.0	18.9	na
number of chiggers/ parasitized bat	19.5	44.0 (2)	0.0	27.7	na
<i>Myotis lucifugus</i>					
% of all captured bats (number captured)	60.6 (20)	57.3 (173)	89.2 (116)	84.4 (309)	na
% parasitism (number infested)	0.0	6.4 (11)	1.7 (2)	4.5 (13)	23.6 (20)
number of chiggers/ captured bat	0.0	0.5	0.02	0.3	1.3
number of chiggers/ parasitized bat	0.0	9.1	1.0	7.9	5.5
<i>Myotis septentrionalis</i>					
% of all captured bats (number captured)	12.1 (4)	4.0 (12)	10.8 (12)	8.2 (30)	na
% parasitism (number infested)	0.0	8.3 (1)	0.0	3.3 (1)	na
number of chiggers/ captured bat	0.0	0.08	0.0	0.0	na
number of chiggers/ parasitized bat	0.0	1.0	0.0	1.0	na

¹Only one trombiculid species (*Leptotrombidium myotis* (Ewing)) was recorded in Ontario.

²Note that a single specimen of *Pipistrellus subflavus* (F. Cuvier) was not included in the analysis hence the total % of bats captured does not equal 100%.

³Four trombiculid species (*Euschoengastia hamiltoni* Brennan, *E. pipistrelli* Brennan, *L. myotis*, and *Neotrombicula microti* (Ewing)) were lumped for the Indiana data (Whitaker 1973).

lucifugus and *M. leibii*. All of the chiggers identified were *Leptotrombidium myotis* (Ewing). *Leptotrombidium* are found on bats and rodents, but *L. myotis* may be restricted to bats (J. O. Whitaker, Jr., personal communication). The relative abundances of bat species at each of the study sites varied significantly (Pearson Chi-square, all $P < 0.0001$), as did the overall prevalence of parasitism at each site (Pearson Chi-square, $P < 0.0001$), and for each species (Pearson Chi-square, $P < 0.0001$).

At Eel Bay and Renfrew, there were significant differences among species in the number of bats parasitized (Pearson Chi-square, $P < 0.0001$ for both). However, when compared across sites, there were no significant differences in the percentage of individuals parasitized (Pearson Chi-square, all $P > 0.05$).

When compared across sites, there was a significant difference between sexes only in the number of *M. lucifugus* parasitized (12 of 202 males parasitized; 1 of 107 females parasitized; Pearson Chi-square = 4.35, $P = 0.037$), but there was no gender-linked difference in infestation intensity (number of chiggers/parasitized male = 8.4; number of chiggers/ parasitized females = 1.0; $F = 0.202$, $P = 0.09$). Only *E. fuscus* exhibited significant

gender-linked differences in infestation intensity with parasitized females subject to heavier infestation than parasitized males (number of chiggers/ parasitized male = 10.7; number of chiggers/parasitized female = 38.0; $F = 7.171$, $P = 0.02$). There was no significant correlation between chigger loads and mass or forearm length for the three species in which more than one individual was parasitized (Pearson correlation; *E. fuscus* $r_{\text{chigger load} \times \text{weight}} = 0.36$, $r_{\text{chigger load} \times \text{forearm length}} = 0.37$, $n = 17$; *M. leibii* $r_{\text{chigger load} \times \text{weight}} = 0.24$, $r_{\text{chigger load} \times \text{forearm length}} = -0.27$, $n = 9$; and *M. lucifugus* $r_{\text{chigger load} \times \text{weight}} = -0.09$, $r_{\text{chigger load} \times \text{forearm length}} = 0.20$, $n = 309$; all $P < 0.05$).

There were significant differences in the parasitism rates between Indiana (Whitaker 1973) and eastern Ontario for *E. fuscus* and *M. lucifugus* (Table 1). *Eptesicus fuscus* had a higher parasitism rate (average chiggers/ captured bat) in eastern Ontario (Pearson Chi-square = 192.43, $P < 0.01$) while *M. lucifugus* had a higher parasitism rate in Indiana (Pearson Chi-square = 180.46, $P < 0.01$). The degree to which individual bats were parasitized also differed between the two regions. Specimens of *E. fuscus* in eastern Ontario were host to more chiggers per bat than in Indiana both when

the total captures were considered as a whole ($t = 2.94$, $P < 0.01$) and when only the parasitized bats were considered ($t = 2.406$, $P < 0.025$). Conversely, specimens of *M. lucifugus* in Indiana were host to more chiggers per bat than in eastern Ontario when the total captures population were considered as a whole ($t = 5.174$, $P < 0.025$), but not when the parasitized bats were analyzed alone ($t = 0.407$, $P < 0.05$).

These data support the view that individual hosts of the same species can differ greatly in parasite loading (e.g., Kennedy et al. 1986) and that regional and local parasite abundances are not necessarily linked (Goater et al. 1987). *Leptotrombidium myotis* is a common parasite of *E. fuscus* and *M. lucifugus* in other regions (Whitaker 1973) but apparently has not previously been reported from *M. leibii* (J. O. Whitaker, Jr., personal communication). A potential reason for the differences noted between Indiana and eastern Ontario is the time of year at which the bats were sampled. As my study covered only a short period of time, it is possible that the infestation intensities I recorded may not be representative of what individual bats face during the remainder of the year. In the southern United States, for instance, larval chiggers can be found throughout the year; however, the active period for chiggers further north (e.g., Ontario) is limited by temperature and may be as short as two months (McDaniel 1979).

The incidence and load of chiggers on bats may reflect the microclimate (as well as location) of the day roosts used by the bats. This is supported by the different incidence of chiggers on male compared to female *M. lucifugus* (Fenton 1970; this study) since males and females of this species occupy different day roosts (Fenton and Barclay 1980). However, if the incidence of chiggers reflects only roost microclimate and location, it may be expected that females would be more heavily parasitized, as maternity roosts are persistent year after year while male day roosts are presumably spread out and more ephemeral (J. O. Whitaker, Jr., personal communication). If the bats are picking up ectoparasites at their roosts, it ought to be more difficult for chiggers to infect male bats. This may be confounded by the fact that many nursery colonies are located in abandoned houses and barns which may not provide suitable habitat for the free-living adults. Obviously, there are other factors at play here, including presence of alternate hosts and the life history traits of adult trombiculids. The data also show differences in infestation intensity between species. While the design of this study does not allow me to comment directly on the reasons for these differences, it does allow me to suggest avenues of research to address this finding. For example, *M. septentrionalis* may use day roosts with different characteristics than those of *E. fuscus* or *M. leibii*, and individuals of the

latter two species may use similar roosts. Examination of trombiculid life-cycles and how they relate to patterns of roost use by bat species would be a logical next step.

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Fire Temperatures in Plant Communities of the Northern Mixed Prairie

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Temperatures during prescribed spring burns were monitored for selected mixed prairie plant communities near Saskatoon, Saskatchewan. In fescue, spear grass, and brome communities the fires peaked quickly at an average maximum temperature of approximately 500°C, then reverted to ambient conditions within about 1 minute. The highest temperatures were recorded 10 cm aboveground. A temperature of 60°C was considered the upper tolerance limit for plant tissue; such conditions persisted for approximately 1 minute within the grass stands. Similar temperatures were observed in a stand of Silverberry. Temperatures above 800°C were recorded in snowberry and aspen and a more protracted cooling phase was noted because of the coarser woody fuel. In all grass and shrub stands there was little change in temperature in the mineral soil at a depth of 5 cm. However, in the aspen grove average temperatures at this depth increased to about 450°C because the thermocouple was embedded in the thick litter layer.

Key Words: Aspen, *Populus tremuloides*; Brome Grass, *Bromus inermis*; Plains Rough Fescue, *Festuca altaica* subsp. *hallii*; fire temperatures, mixed prairie; Silverberry, *Eleagnus commutata*; Snowberry, *Symphoricarpos occidentalis*; Spear Grass, *Stipa comata*; Saskatchewan.

The warm summers on the Canadian prairies favor development of convectional storms, often accompanied by severe lightning and the threat of fire. Thus, Rowe (1969) documented more than 30 lightning fires in southern Saskatchewan during 1967. Similarly, in North Dakota grasslands lightning fires can occur in any month from April to September (Higgins 1984). Evidence of lightning fires is found in various historical accounts, and there is a long record of fire use by indigenous populations to encourage new plant growth to attract bison (Nelson and England 1971). However fire frequency increased in the early settlement period, especially with the development of the railways (Raby 1966).

The concerns of the early European settlers led to the enactment of various fire control measures, and ultimately the threat of wildfire was reduced as native prairie was converted to agriculture. Over time the abundant fine fuels were replaced by domestic forage grasses and cereal crops, the land was subdivided by grid roads which acted as fire breaks and efficient fire fighting equipment was introduced. Recognition of vegetation changes associated with this modified fire regime has led to a growing awareness of the importance of fire in the preservation of remnant native grasslands (Daubenmire 1968; Vogl 1974; Wright and Bailey 1980) and prescribed burning is now widely practiced in range management. Fire has been used to stimulate new plant growth (White and Currie 1983) and to increase palatability of forage (Redmann et al.

1993). Fire has also been used to eliminate weeds (Grilz and Romo 1995) and to reduce woody species (Bailey et al. 1990). In addition, burned areas can provide a patchy landscape and so increase biodiversity (Belsky 1992).

The ecological effects of fire in grasslands have been studied extensively, but less information is available on temperature duration profiles during a burn. The effect of fire on vegetation depends on such things as fire intensity, duration of lethal temperatures, and depth of heat penetration in the smoldering fuels on the soil surface. In this study calibrated thermocouples were used to monitor temperature patterns in grass, shrub and tree communities in northern mixed prairie and fescue prairie during controlled spring burns.

Methods

Fire experiments were conducted at two sites near Saskatoon, Saskatchewan (52° 11'N, 106° 42'W). A stand dominated by Plains Rough Fescue (*Festuca altaica* subsp. *hallii*) and an aspen (*Populus tremuloides*) grove were located at Kernen Prairie, a remnant fescue grassland associated with clay soils about 5 km east of Saskatoon. Additional stands dominated by Brome Grass (*Bromus inermis*), Spear Grass (*Stipa comata*), Snowberry (*Symphoricarpos occidentalis*) and Silverberry (*Eleagnus commutata*) were studied on mixed prairie established on sandy soils at Beaver Creek Conservation Area about 15 km south of Saskatoon.

Fuel loads were assessed by clipping standing vegetation from twelve 50 × 50 cm quadrats spaced at 5 m intervals on a transect through each stand. The height of the canopy at each sampling point was recorded prior to clipping. Woody material was separated from herbaceous material and litter was also collected from the soil surface. The fresh weights of different plant materials were recorded, and the samples dried in convective ovens at 85°C for 48 hours and reweighed to determine moisture content of the fuel (% dry weight). In addition, twelve trees were randomly selected in the aspen grove and felled. The trees ranged from 2.5 to 6.9 cm in diameter at breast height and 2.5 to 7.0 m in height; moisture content was determined for subsamples of the trunks and branches.

Fire temperatures were measured with type-K thermocouples constructed from 20-gauge chromel-alumel wire insulated with braided fiberglass. These devices have a temperature range of -250°C to 1260°C and a response time of about 3 seconds; their sensitivity is $\pm 1^\circ\text{C}$ below 500°C and $\pm 3^\circ\text{C}$ above 500°C which is ideal for fire temperature measurements. Each thermocouple was made from 10 m lengths of double-stranded wire by removing 1 cm of insulation and twisting the bare ends together; this junction was then arc welded. Enough thermocouples were made to provide six samples at each of 7 heights within each stand of vegetation. The thermocouples were installed on metal posts at 10 cm, 25 cm, 50 cm, 100 cm and 150 cm above ground level. Additional probes were placed on the ground surface and at a depth of 5 cm in the soil. The probes were connected to Campbell Scientific CR10 microloggers programmed to record data at 10 second intervals. Because the thermocouple leads were comparatively short, the dataloggers had to be placed within the fire area. An enclosure of concrete blocks packed with fiberglass provided adequate protection from the flames. Before each burn a fire break was mowed and burned around the stands to provide an area of about 75 × 75 m that was subsequently burned in a headfire. The fires were set in the afternoon in late April and early May when air temperature was 15-18°C, relative humidity 30-40% and windspeed less than 3 m s⁻¹.

Results

(a) *Fuels* — Fuel loads in the grass stands ranged from 281 g m⁻² in Spear Grass to 451 g m⁻² in fescue (Table 1). Standing biomass in fescue accounted for approximately 40% of the fuel, the remainder was represented by litter and lodged materials. The top of the fescue canopy was approximately 35 cm. In Spear Grass and brome approximately 60% of the fuel was standing and the remainder comprised of relatively intact grass litter. The erect shoots of Spear Grass provided an open canopy about 10 cm

tall, compared to a mixture of dead stems and overlapping leaves to a height of about 75 cm in brome. Moisture content was considerably higher in fescue ($44 \pm 12\%$) compared to $18 \pm 6\%$ and $18 \pm 4\%$ in Spear Grass and brome, respectively.

Biomass in the Snowberry stand averaged 1029 g m⁻². Of this approximately 50% was fine woody material less than 5 mm in diameter growing to a height of about 50 cm, and the remainder was mixed litter comprised of leaves, fine twigs and grass. Moisture content of the Snowberry fuel averaged 25%. Average biomass in the Silverberry stand was 911 g m⁻² of which approximately 30% was litter and grass and the remainder woody stems up to 2 cm in diameter growing to a height of about 1.7 m. Average moisture content for this fuel was 31%. In the aspen grove woody components averaged 4263 g m⁻² with an additional 971 g m⁻² in the understory and litter. Moisture content of these two fuel types was 63% for the woody material and 28% for the grasses, herbs and litter.

(b) *Fire temperatures* — The general pattern of fire temperature is similar in each of the prescribed grass fires, with temperatures quickly peaking at about 500°C, then falling to ambient temperatures within about 1 minute (Figure 1, Table 2). The highest temperatures were recorded at 10 cm above-ground and decreased progressively with height. Average maximum temperatures ranged from 444°C in spear grass to 474°C in brome. Similarly, the brome stand generated the highest temperatures in the surface litter averaging 357°C compared to 189°C and 209°C in fescue and Spear Grass, respectively. Despite the high ground surface temperatures, there was no significant rise in soil temperatures at a depth of 5 cm in any of the grass stands.

Fire in the Snowberry stand produced a temperature pattern similar to that recorded in the grasses with a rapid rise and fall as the fire front passed through the stand (Figure 2, Table 2). However, maximum temperatures were considerably higher and more consistent in the Snowberry stand. Thus, at

TABLE 1. Average total fuel load and fuel moisture content in selected prairie stands.

	fuel load (g m ⁻² dry weight \pm S.D.)	moisture content (% \pm S.D.)
Fescue	451 \pm 170	44 \pm 12
Spear Grass	281 \pm 136	18 \pm 6
Brome	372 \pm 142	18 \pm 4
Snowberry	1029 \pm 228	25 \pm 8
Silverberry	911 \pm 343	31 \pm 24
Aspen		
— standing wood	4263 \pm 2658	63 \pm 35
— understory and litter	971 \pm 107	28 \pm 4

TABLE 2. Average maximum fire temperatures ($^{\circ}\text{C} \pm$ standard deviation, at various heights in selected prairie stands.

	Probe height						
	-5 cm	0 cm	10 cm	25 cm	50 cm	100 cm	150 cm
Fescue	6 \pm 9	189 \pm 146	468 \pm 216	432 \pm 40	309 \pm 109	264 \pm 79	193 \pm 44
Spear Grass	14 \pm 1	209 \pm 140	444 \pm 79	388 \pm 57	285 \pm 60	207 \pm 62	173 \pm 36
Brome	17 \pm 6	357 \pm 142	474 \pm 59	414 \pm 65	345 \pm 76	321 \pm 150	281 \pm 128
Snowberry	40 \pm 21	692 \pm 118	843 \pm 36	824 \pm 43	835 \pm 54	735 \pm 11	697 \pm 22
Silverberry	37 \pm 16	180 \pm 123	551 \pm 154	395 \pm 147	306 \pm 153	195 \pm 104	178 \pm 114
Aspen	452 \pm 141	589 \pm 152	703 \pm 60	710 \pm 76	586 \pm 150	462 \pm 171	415 \pm 179

10 cm the average maximum temperature was 843°C decreasing to 697°C at 150 cm and to 692°C at the ground surface. Such high temperatures resulted in a more protracted cooling phase compared to the grass stands; at 0 and 10 cm temperatures persisted above general ambient conditions for about 5 minutes after the fire. The intense heat from the fire increased average maximum soil temperature to 40°C at a depth of 5 cm.

Average maximum temperatures were comparatively lower in the Silverberry stand, reaching 551°C at 10 cm and dropping progressively to 178°C at 150 cm which approximated the top of the vegetation canopy. Maximum temperature at the ground surface averaged 180°C , but the litter, comprised of a mixture of leaves and coarser woody fragments, continued to smolder for some time. Temperatures remained above prefire conditions for 3 to 4 minutes on average.

Maximum fire temperatures within the aspen grove ranged from an average of 415°C at 150 cm to 710°C at 25 cm. The subsurface thermocouple probes were embedded in the thick litter layer, and recorded an average maximum temperature of 452°C at a depth of 5 cm. Temperatures rose rapidly as the fire front burned through the grove, but fell rather slowly until the woody material burned out. Temperatures remained above pre-fire conditions for at least 12 minutes at all heights aboveground. The cooling phase was most protracted at the ground surface and became progressively shorter with height above the smoldering ashes. Temperatures below-

ground returned to prefire conditions within about 2 minutes.

(c) *Temperature duration* — Exposure to temperatures of about 60°C is considered lethal for plant tissues (Daniell et al. 1969; Brown and Davis 1973). In the very hot fire which occurred in the Snowberry stand aboveground temperatures exceeded 60°C for between 2.2 and 8.1 minutes (Table 3). In the cooler Silverberry fire lethal temperatures persisted for between 0.8 and 3.3 minutes. The longest duration was recorded at 10 cm in the aspen grove where temperatures remained above 60°C for 9.8 minutes. In the grass communities the finer fuels were consumed more rapidly and lethal temperatures typically persisted for about 1 minute. Temperatures at 5 cm belowground rose above 60°C only in the Snowberry and aspen stands. In the Snowberry stand lethal soil temperatures persisted for only 7 seconds, but in the aspen litter the average duration was 2.7 minutes.

Discussion

Fire temperatures are dependent on a variety of factors including fuel loads, fuel moisture content and weather conditions at the time of the burn. The fescue stand was the first to be burned early in the spring; this accounts for the higher fuel moisture content, although the compact form of this species and low standing biomass compared to litter and lodged material may also have influenced fire temperature. In addition, the underlying clay soils dried more slowly than the sandy soils at the Spear Grass and Brome site. Fuel moisture content varied by as

TABLE 3. Average duration (minutes \pm standard deviation) of fire temperatures above 60°C at various heights in selected prairie stands.

	Probe height						
	-5 cm	0 cm	10 cm	25 cm	50 cm	100 cm	150 cm
Fescue	0 \pm 0	1.0 \pm 0.9	1.8 \pm 0.6	1.1 \pm 0.3	0.8 \pm 0.2	0.8 \pm 0.1	0.7 \pm 0.1
Spear Grass	0 \pm 0	1.2 \pm 1.0	1.4 \pm 0.6	1.1 \pm 0.2	1.0 \pm 0.1	0.8 \pm 0.1	0.9 \pm 0.1
Brome	0 \pm 0	2.6 \pm 0.9	1.4 \pm 0.3	1.1 \pm 0.2	1.1 \pm 0.2	1.1 \pm 0.3	1.2 \pm 0.4
Snowberry	0.1 \pm 0	8.1 \pm 6.0	4.7 \pm 1.1	3.5 \pm 0.5	3.1 \pm 0.5	2.3 \pm 0.5	2.2 \pm 0.6
Silverberry	0 \pm 0	3.3 \pm 2.9	2.0 \pm 0.4	1.6 \pm 0.4	1.3 \pm 0.3	1.0 \pm 0.3	0.8 \pm 0.3
Aspen	2.7 \pm 1.5	6.3 \pm 7.6	9.8 \pm 1.7	6.7 \pm 1.9	6.5 \pm 2.0	5.8 \pm 0.2	5.5 \pm 1.5

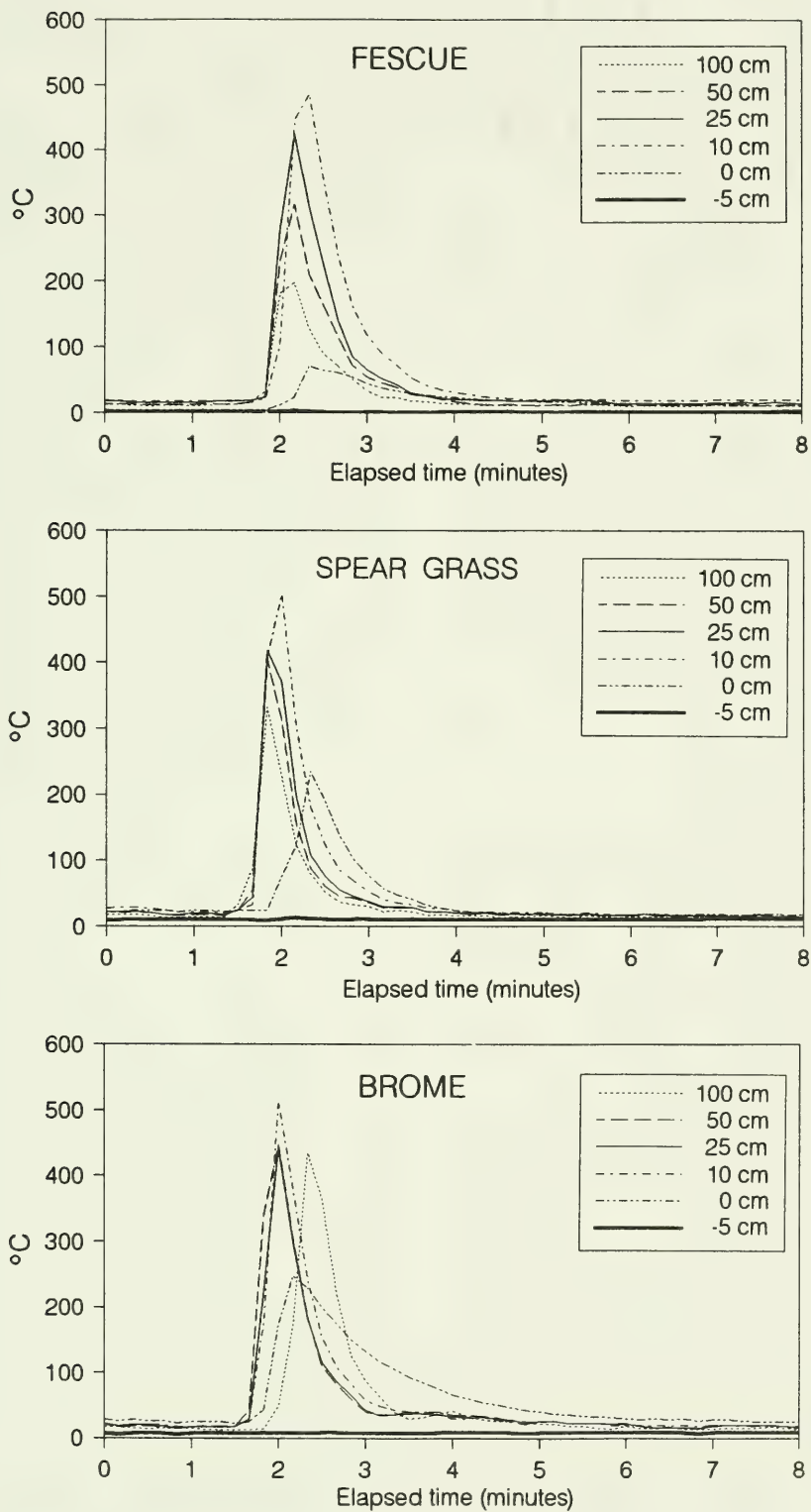


FIGURE 1. Representative temperature-time duration curves in prescribed burns in Plains Rough Fescue, Spear Grass and Brome Grass communities in the mixed prairie grasslands of Saskatchewan.

much as 31% within the fescue stands and by as much as 77% within the Silverberry stand; fuel loads varied by about 30% within each of the grass and shrub stands. Conditions were even more variable within the aspen stand. These variations explain the wide range of fire temperatures noted within and between the different stands.

In general, fire temperatures increase with higher fuel loads. For example, Stinson and Wright (1969) noted an increase in maximum soil surface temperatures from 83 to 682°C as fuel loads increased from 1732 to 7868 kg ha⁻¹ in experimental burns conducted in various grasslands in Texas. A similar relationship was reported in grass and shrubland communities in Alberta (Bailey and Anderson 1980). However, the nature of the fuel is important, and as the proportion of woody material increases there is a corresponding delay in ignition which can reduce maximum fire temperature (Anderson 1970). Moisture content of the fuel also affects fire activity. Thus, aspen stands are more susceptible to fire in late spring when the cured surface vegetation and leaf litter dry out through exposure to wind and sun. Indeed, Bailey (1988) recommended that prescribed burns be conducted about 10 drying-days after snowmelt, when air temperature is at least 18°C and relative humidity below 30%. Later in the summer aspen stands can be impenetrable to fire because of high leaf moisture content in the canopy and understory (Quintillo et al. 1991).

The fire temperatures reported in this study are generally higher than those reported in a comparable study by Bailey and Anderson (1980). They reported temperatures at the soil surface ranging from 93 to 427°C in headfires in grassland, increasing to a range of 232 to 704°C in shrubs and 260 to 982°C in aspen forest. Bailey and Anderson (1980) also noted that temperatures increased above ground to a height of 15-20 cm then declined steadily above this. There is no record of duration because these temperatures were established using fire sensitive pellets.

The rapid passage of fire through the fine grass fuels with very little change in temperatures in the underlying soils is consistent with results presented elsewhere. In grassland fires in New South Wales for example, soil temperatures at a depth of 15 cm reportedly remained below 30°C (Norton and McGarity 1965). Higher soil temperatures have been reported in grass fuels in California (Bentley and Fenner 1958); here temperatures decreased from 121°C at the soil surface to 82°C, 74°C, 63°C and 57°C, respectively at depths of 2.5, 5.0, 7.5 and 10 cm. Similarly, Schimmel and Granstrom (1996) noted a steep decline in maximum temperatures with depth beneath experimental fires in mixed spruce-pine forests in Sweden. There temperatures above 60°C were reported at a depth of 20-30 mm below charred coniferous litter, but in mineral soil lethal

temperatures were not reached below about 10 mm even though temperatures as high as 632°C occurred in the smoldering litter

In order to survive fire, plant material must either be tolerant of high temperatures or be buried deep enough to avoid them. Rhizomes of *Vaccinium* spp. and *Deschampsia flexuosa* were killed by 10 minutes exposure to temperatures of 55 to 59°C (Schimmel and Granstrom 1996), and seeds of weed species including Wild Oats (*Avena fatua*), Red Root Pigweed (*Amaranthus retroflexus*) and Lamb's Quarters (*Chenopodium album*) were killed after 15 minutes exposure to temperatures of 85-104°C (Hopkins 1936). However, heat penetration in soils is dependent on texture and moisture content. Heat penetrates moist soils slowly because of the large heat of vaporization of water and is also controlled by the relative ease with which water vapour can move through a porous soil (Aston and Gill 1976; Campbell et al. 1995).

Most of the native species of the northern grasslands are adapted to fire and are able to regenerate vegetatively from underground organs. Snowberry resprouts quickly following spring fires (Anderson and Bailey 1979); its deep rhizomatous growth form is well-adapted to fire (Pelton 1953). Silverberry is similarly protected by roots which spread out at depths of 30-60 cm (Whysong and Bailey 1975). Aspen is very susceptible to fire and may be killed directly or succumb to fire-induced stress after 1 or 2 years. However, aspen is renowned for its prolific suckering and new stems develop from the shallow roots as much as 18 cm below the soil surface (Brown and DeByle 1987); this is well below the zone of soil temperature increase noted in the present study.

This study found that very little heat was transferred into the mineral soil during spring burns. Vigorous regrowth was noted at all stands within one month of the fires, indicating that reproductive organs were undamaged. Successive spring fires over several years could effectively reduce the seed-bank of weedy species which contribute seeds to the litter layer during interfire periods. Better weed control could be achieved by hotter fires with greater heat penetration; this would require a different burning regime. For example, back burns would generate more heat because of their slower rate of spread, while summer or fall burning could take advantage of higher air and soil temperatures, lower humidities and drier fuels. Summer burns are most destructive of young plants while late season fires have the potential of killing seeds which have not yet been dispersed or which have been recently deposited in the surface litter. A combination of chemical treatment and fire has been used to control European Buckthorn in an aspen stand near Saskatoon (Delaney, personal communication). The stems were

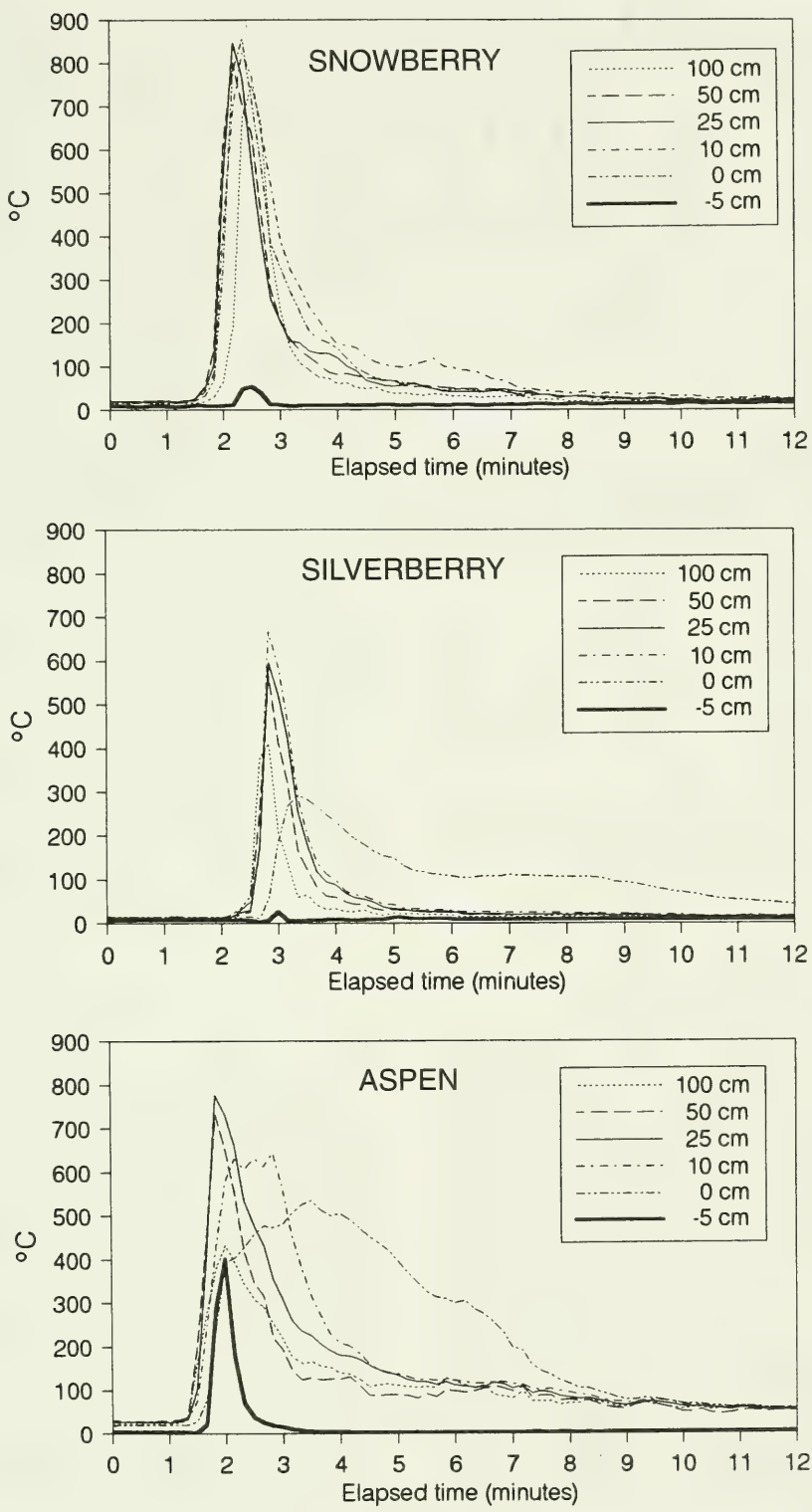


FIGURE 2. Representative temperature-time duration curves in prescribed burns in Snowberry, Silverberry and Aspen communities in the mixed prairie grasslands of Saskatchewan.

first killed by herbicide creating a higher fuel load of standing dead wood; this presumably increased fire temperatures and resulted in effective reduction of seeds and seedlings of the invasive shrub while the native aspen regenerated from suckers deeper in the soil. Long-term maintenance of stands of restored native vegetation may ultimately depend on appropriate fire strategies. Knowledge of seed, rhizome and root depths, as well as lethal temperatures for native and introduced species coupled with soil temperatures resulting from different burning practices are therefore needed to develop effective management strategies.

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Observations of Fish Mortality Associated with Ice Blasting on the Lower Rideau River, Ottawa, Ontario

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Six days of the annual ice blasting program were monitored to assess blast-induced fish mortality. We observed 569 fish mortalities in two reaches of the Lower Rideau River (Ontario, Canada) during the two monitoring periods. Rock Bass, *Ambloplites rupestris*, was the most commonly observed fish killed (81% of total mortalities) in each of the two reaches assessed. The numbers of dead fish observed during the blasting program were highly variable and presumably dependent on the site-specific habitat characteristics at each blast location. All but two fish mortalities were observed on or just below the water surface. Our observations suggest that considerable numbers of fish, of primarily small sizes classes, are killed during the annual ice removal program. Our findings also suggest that some mortalities may sink to the bottom and are difficult to quantify due to the hazardous conditions of the ice blasting exercise.

Key Words: Blasting, ice removal, fish, Rideau River, Rock Bass, *Ambloplites rupestris*.

The removal of ice using explosives has been a part of the annual ice management program on the Lower Rideau River (45°41' N, 75°26' W) to prevent ice jam-induced flooding of residential areas in the cities of Ottawa and Vanier (Ontario, Canada) for over 100 years. Despite the long-term success of ice management and flood control in minimizing flood risk, the environmental implications of the program are largely unknown. Observations of fish mortalities have been reported from along the river margins during ice blasting operations and during spring thaw. Most of these mortalities are presumed to occur in response to the subsurface concussions of the blasting program.

The underwater detonation of explosives is primarily associated with seismic exploration and research, and underwater construction and maintenance projects. Several Canadian communities use explosives as a proactive or reactive measure to avoid ice jam-induced flooding. While only a few studies have assessed blast-induced fish mortality related to construction (Teleki and Chamberlain 1978; Griffiths 1989) and seismic surveying (Muth 1966; Patterson and Turner 1968; Falk and Lawrence 1973), we were unable to identify any fish mortality data related to ice-blasting.

In 1994, the Rideau Valley Conservation Authority (RVCA) initiated an environmental review of ice management practices and the overall flood control program on this reach of the Rideau River which is located between, and isolated by, Prince of Wales Falls and Rideau Falls. Within the environmental review we identified the opportunity to pro-

vide some quantitative estimate of fish mortality associated with the 1994 ice-blasting program. This paper reports our observations of fish mortality made immediately downstream of the blasting area on two reaches of the river.

Methods

The ice blasting program is conducted by specially-trained City of Ottawa employees. In 1994, dynamite charges (ETI Tovex Blastrite #3) weighing either 500 or 1000 g were placed at the ice-water interface in pre-drilled holes and individual dynamite charges were detonated, randomly, at four locations spaced equidistant across the width (approximately 100 m) of the river. Fractured ice packs were dislodged from the main river ice cover by waves and prop-wash generated by two motorized steel-hulled boats. Removal of dislodged ice was aided by flow augmentation achieved through the management of water levels in reservoirs far upstream of the study area. During the 1994 monitoring period, approximately 200 charges per day were detonated. An estimated 6370 kg of explosive and 5800 blasting caps were used over the 28-day ice removal program in 1994. Pressures exerted by the detonation of explosives were not measured.

Observations of the ice blasting program were conducted between 9 and 12 March, and 30 and 31 March, 1994 covering 6 days (21%) of the 28-day ice removal program which was initiated on 6 March and concluded on 2 April. Blasting operations during these observation periods were conducted along a 2 km reach from New Edinburgh Park to just

upstream of the St. Patrick Street Bridge, and a 2.5 km reach from upstream of the Hurdman Bridge to the George McIlraith Bridge. From a motorized aluminum boat travelling through the freshly broken ice packs immediately downstream of the blasting area, we monitored the approximate numbers and species composition of floating fish stunned or killed by the blasting operation. The entire width of the river was scanned by travelling back and forth through the ice floes although regular transects could not be achieved due to the difficulties of navigation. Areas further downstream, and more removed from the immediate blasting zone, were also periodically checked for floating fish, including those that may have surfaced beyond the primary observation area. Where possible, dead fish were netted and examined for obvious external damage or lesions from the blast concussion. Not all fish were collected due to their location amidst the ice packs relative to the boat and/or when large numbers of fish surfaced. In some cases, we were therefore unable to distinguish, with certainty, between species of similar shape and colour. Consequently, several species of cyprinids were grouped, as were two species of sunfish (Bluegill, *Lepomis macrochirus*, and Pumpkinseed, *Lepomis gibbosus*).

Mortalities within the water column or sinking to the river bottom were not assessed during the operational blasting period due to the hazards and difficulties associated with working in the active blasting area and amidst the broken ice packs. At night, when blasting had ceased and the broken ice had cleared from the river, a glass-bottomed box was affixed to the side of the boat in an attempt to visually observe dead fish on the river bottom (i.e., dead fish which did not float). An onboard portable generator powered three Halogen floodlights attached to the outside of the box to illuminate the river bottom. Dead fish located on the bottom were collected with a long-handled dip net. Night observations were limited

by water clarity (i.e., < 2 m depth) allowing only a small percentage (< 5%) of the river bottom in the blasting area to be inspected.

Results and Discussion

Table 1 presents the numbers, species and length ranges of mortalities for each of the two study area reaches assessed. Rock Bass (*Ambloplites rupestris*) was the most abundant species observed during both survey periods representing over 80% of all fish mortalities observed. Yellow Perch (*Perca flavescens*) was the next most frequently observed (9% of total mortalities). All other species observed accounted for less than 10% of the total mortalities. Predominant species within the "cyprinid" and "sunfish" groups of mortalities were Spottail Shiner (*Notropis hudsonius*) and Pumpkinseed, respectively.

Within the scope of our study we were unable to examine the distribution or composition of the winter fish community. Unpublished netting data were obtained from the local Ontario Ministry of Natural Resources (OMNR) office for several locations between the two impassable barriers represented by Prince of Wales Falls and Rideau Falls to assist in the characterization of the Lower Rideau River fish community. Species collected by the OMNR, but not observed during the ice-blasting monitoring periods were Longnose Gar (*Lepisosteus osseus*), Muskellunge (*Esox masquinongy*), Brown Bullhead (*Ameiurus nebulosus*), Channel Catfish (*Ictalurus punctatus*), Largemouth Bass (*Micropterus salmoides*), and Black Crappie (*Pomoxis nigromaculatus*). The Rideau River also supports other species which were not collected by the OMNR or observed in this study.

Numbers of dead fish collected throughout the blasting period were highly variable and presumably dependent on specific habitat characteristics at each blast location. For example, no fish would be

TABLE 1. Summary of composition, abundance and length range of fish mortalities observed during the 1994 ice removal program on the Lower Rideau River, Ontario.

Fish Species	Mortalities			Total Length Range (mm) ¹
	March 9-12	March 30-31	Total	
Rock Bass, <i>Ambloplites rupestris</i>	105	355	460	33 – 202 (35)
Yellow Perch, <i>Perca flavescens</i>	15	38	53	80 – 220 (16)
Cyprinids	0	18	18	75 – 120 (5)
Sunfish	0	16	16	120 – 160 (4)
Common Carp, <i>Cyprinus carpio</i>	7	0	7	659 – 738 (3)
White Sucker, <i>Catostomus commersoni</i>	1	6	7	281 – 472 (7)
Northern Pike, <i>Esox lucius</i>	0	3	3	290 – 433 (3)
Walleye, <i>Stizostedion vitreum</i>	0	2	2	165 – 311 (2)
Smallmouth Bass, <i>Micropterus dolomieu</i>	2	0	2	72 – 196 (2)
River Redhorse, <i>Moxostoma carinatum</i>	0	1	1	612 (1)
Total	130	439	569	

¹ Number of fish measured in parentheses.

observed following a sequence of 10 to 20 blasts. Following the next blast however, 20 fish could surface. Proximity to shore and depth were also parameters relevant to observed blast-induced fish mortality. At one nearshore location, for example, high mortality of juvenile Rock Bass was observed presumably indicating that the area was being used as an overwintering area and/or that blast pressures were substantially higher at this location. As it was not possible to collect mortalities separately for each blast, we were unable to quantify this variability. The numbers and species of mortalities also varied with the reach of river assessed. Over 75% of the total mortalities observed occurred in the reach between the Hurdman Bridge and the George McLraith Bridge (i.e., second survey period).

A broad range of fish sizes were represented by the observed mortalities although Rock Bass and Yellow Perch mortalities were predominantly of smaller sizes (i.e., <100 mm total length). The largest dead fish collected during the observation period was a Common Carp (*Cyprinus carpio*) (738 mm).

With the exception of two Smallmouth Bass (*Micropterus dolomieu*) which were collected from the river bottom, all fish mortalities were observed floating at or near the water surface. Most were observed floating on their sides. All observed Northern Pike (*Esox lucius*), Walleye (*Stizostedion vitreum*) and larger Yellow Perch were found floating belly side up. Relatively few fish (i.e., 5 or 6) were observed with external lesions or scars which may have been caused by contact with the fractured ice blocks or contact with the propellers of boats used to dislodge broken ice. Other external lesions were exhibited by about ten of the fish collected and included flared gills and haemorrhaging at fin origins, particularly the caudal peduncle. All observed fish appeared to be freshly killed.

Susceptibility of fish to the damaging effects of blasting has been reported to be a function of the fish's shape (Teleki and Chamberlain 1978) and size (Yelverton et al. 1975). Rock Bass appeared to be the most sensitive fish species of the Lower Rideau River fish community to blasting effects. While probably one of the most abundant species in the river, their laterally compressed bodies (i.e., high surface area) render them highly susceptible to blasting effects. Teleki and Chamberlain (1978) noted laterally-compressed species such as Pumpkinseed, Crappie (*Pomoxis* spp.) and White Bass (*Morone chrysops*) to be most sensitive to open-water blasting in Lake Erie. Species considered to be least sensitive to blasting effects had fusiform body shapes such as Rainbow Trout (*Oncorhynchus mykiss*), White Sucker (*Catostomus commersoni*) and Yellow Bullhead (*Ameiurus natalis*) (Teleki and Chamberlain 1978). Muth (1966) reported Northern

Pike, a species having an extremely fusiform body shape, to be the least sensitive of the species examined to high pressure changes associated with blasting. White Sucker, Northern Pike and several other species resident in this segment of the Rideau River and having cylindrical body shapes were uncommon in observations of mortalities during the 1994 ice removal program on the Lower Rideau River. Yelverton et al. (1975) demonstrated that fish mortality decreased with increasing fish weight (i.e., small fish were more susceptible to blast-induced mortality). Our observations of predominantly small Rock Bass and Yellow Perch mortalities appear to corroborate the findings of Yelverton et al. (1975).

Of the total number of fish mortalities (569) observed or collected over the 6-day survey period, only two mortalities were observed on the river bottom. Teleki and Chamberlain (1978) reported that other studies of blasting effects on fish found that between 11 and 50% of all fish killed sank to the bottom. In their study (Teleki and Chamberlain 1978), a variety of fish species were collected from the surface but only the Emerald Shiner (*Notropis atherinoides*) was collected in subsurface tows. Griffiths (1989) found that only Alewife (*Alosa pseudoharengus*) were killed by open-water blasting in eastern Lake Ontario and confirmed, with the use of lift nets and diver surveys, that nearly all fish rose to the surface within a few minutes of the blast. Patterson and Turner (1968) also reported that all dead or injured fish floated to the water surface. Our assessment of fish mortality on the river bottom was limited to night observations of shallow water areas, usually a maximum depth of 2 to 2.5 m. Deeper areas could not be assessed due to turbidity. Netting or diving in the vicinity of the ice-blasting operations on the Lower Rideau River was too hazardous. Given these limitations, we were unable to more fully assess "sinking" mortalities resulting from the ice blasting program.

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Reproductive Biology of the Northern Madtom, *Noturus stigmosus* (Actinopterygii: Ictaluridae) in Lake St. Clair, Ontario

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During the summer of 1996, the Northern Madtom, *Noturus stigmosus*, was found in artificial nests being used to study the reproductive biology of the exotic fish, *Neogobius melanostomus* (Round Goby). At one site in Lake St. Clair, near the source of the Detroit River, Northern Madtoms were observed to be guarding egg clutches. Total lengths of mature male and female madtoms were measured from video using computer image analysis. Clutch size, egg diameter, and juvenile length also were determined using computer image analysis. This is the first known reproducing population of the Northern Madtom in Canada.

Key Words: Northern Madtom, *Noturus stigmosus*, chat-fou du nord, reproduction, early life history, Lake St. Clair, Ontario.

The Northern Madtom, *Noturus stigmosus* Taylor, 1969, is a small catfish belonging to the bullhead catfish family Ictaluridae. In 1963, a single specimen was collected from Lake St. Clair near the source of the Detroit River (Trautman 1981). A second individual was not collected near that location until 1994 (Royal Ontario Museum fish catalogue number 68328). Currently the status of this species in Canada is listed as Indeterminate (Campbell 1997) by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). E. Holm and N. E. Mandrak have prepared an updated status report on the species which is currently under COSEWIC review.

Although the genus *Noturus*, the madtoms, is the most speciose of the family Ictaluridae, the ecology of the members of this genus is poorly understood. This is likely a result of their small size, secretive nature, and lack of economic or sport value (Scott and Crossman 1973). Prior to 1985, life history information was only available for 15 of the 26 species in this genus (Starnes and Starnes 1985) and since then only three other studies have been published on the reproductive traits of this genus (Simonson and Neves 1992; Baker and Heins 1994; Pflingsten and Edds 1994).

The spawning season for all madtoms occurs during the spring and summer although the exact timing depends on the species and the locale (Pflingsten and Edds 1994). In the Northern Madtom spawning occurs during mid to late July in Michigan (Taylor 1969). Like other madtoms and ictalurid catfishes, *N. stigmosus* is a cavity spawner (Mayden and Burr 1981; Holland-Bartels et al. 1990) and the eggs are guarded by the male (Burr and Mayden 1982). During the summer of 1996, Northern Madtoms

were found to shelter in and construct nest cavities under artificial nests. The original purpose of these nests was for a study of the reproductive biology of the Round Goby, *Neogobius melanostomus* (Gobiidae), an exotic fish in the Great Lakes. Males of the Round Goby also guard their eggs, which are spawned on the roofs of suitable cavities. With such similar reproductive strategies, the potential exists for competition between these two species. The Round Goby has already been implicated in the severe decline of the Mottled Sculpin (Cottidae; *Cottus bairdi*) population and in apparent declines in the Logperch (Percidae; *Percina caprodes*) population in the St. Clair River (Jude et al. 1995). This study documents the first known breeding population of the Northern Madtom in Canada and describes some aspects of the reproductive biology of this population.

Materials and Methods

Artificial nests were placed at four sites in the upper Detroit River and western Lake St. Clair but Northern Madtoms were observed at three of the four sites and spawning was only observed at one of these three sites. This study site was located approximately 50 m offshore from Sandpoint Beach municipal park (Windsor, Ontario) on Lake St. Clair (42°20'20"N, 82°55'05"W), near the outflow into the Detroit River (Figure 1). The water depth at the site varied from 1.5–1.8 m and there was a noticeable current flowing west into the Detroit River. The substrate was sand with occasional cobble. A heavy growth of macrophytes (predominately *Chara*) carpeted the bottom throughout most of the summer. The other two sites where Northern Madtoms were observed were located within the range of Northern



FIGURE 1. The upper Detroit River and western Lake St. Clair showing the site where Northern Madtom reproduction was observed (closed circle) and the locations where Northern Madtoms were captured while trawling (open circles) during summer and fall 1996.

Madtom captures (Figure 1) but both sites had a cobble substrate. The macrophyte community at each site consisted of *Vallisneria* and *Cladophora*, respectively. No madtoms were observed at the fourth site which was located west of the Northern Madtom capture locations. The substrate at this site was predominately silt. Water depth and current was similar at all sites.

The artificial nests (15 cm long \times 10 cm wide \times 5 cm high) were composed of two separate pieces and had one open end. The upper and sides of the nest were constructed of ceramic tile cemented with silicone and the removable lower portion of the nest was a half-section of PVC pipe. The pipe was inserted in the ceramic box with the outside curve of the pipe facing down. This was to ensure that the nest would only have a single opening and would potentially be a more attractive nest cavity. Thirty-six nests were placed in a 6 m \times 6 m grid with the open end randomly oriented either north, south, east, or west. Nests were placed in the field using SCUBA on 25 June 1996 and examined on 17 July, 24 July, and 13 August 1996. On 17 July nests were examined visually for the presence/absence of Round Goby eggs. The presence of other organisms in the nests was also recorded. On 24 July and 13 August the nests were recorded on video using a black and white video camera in a waterproof housing. The camera was connected by cable to a video cassette recorder on the boat.

The videotape was then analyzed in the lab using

computer image analysis (Mocha System, Jandel Scientific, California). Images from the video were captured by the image analysis program and each image was individually calibrated using the artificial nest as the scale reference. Following calibration, the total lengths of adult *N. stigmatosus* were measured, the number and diameter of eggs in a clutch was determined and when present, an attempt was made to determine the lengths of *N. stigmatosus* larvae.

Results and Discussion

Northern Madtoms were first observed occupying the artificial nests on 17 July 1996 (Figure 2). Rather than spawning in the nest itself, the madtoms excavated a cavity about 5 cm in depth, in the sand substrate beneath the nest (Figure 2). The Northern Madtom, like other madtom species, typically constructs a nest in cavities underneath rocks or logs and inside crayfish burrows or cans (Taylor 1969; Mayden and Burr 1981; Cochran 1996). Mayden and Burr (1981) speculated that madtom catfishes potentially could compete with other species for nest sites. This situation is now occurring in the upper Detroit River with the introduced Round Goby which also constructs nests in cavities (Jude et al. 1995; Marsden et al. 1996). The extent of interactions between these two species is unknown, but Northern Madtoms seem to have competed successfully against the Round Goby for available artificial nests at the Sandpoint Beach site. Interestingly, of the four sites where artificial nests were placed, the site



FIGURE 2. Male Northern Madtom with egg clutch (exposed by removal of artificial nest). Note the shallow cavity excavated by the madtom.

reported in this paper had the highest occurrence of Northern Madtoms but the lowest occurrence of Round Goby reproduction. The reasons for the low rate of Round Goby reproduction are unknown. The other two sites where Northern Madtoms were observed had higher rates of Round Goby reproduction than at the Sandpoint Beach site. Higher densities of adult Round Gobies at these sites may have prevented Northern Madtom males from successfully obtaining nest sites.

On 17 July, four nests were occupied and each nest contained an egg clutch guarded by a single madtom at the Sandpoint Beach site. Due to a camera malfunction it was not possible to record the nests on video. One week later, on 24 July, the site was revisited and two of the four nests still contained madtom eggs and a new clutch was present. The other two nests which had contained eggs on 17 July no longer contained eggs or larvae but one of the nests did contain a madtom pair. The fate of the eggs is unknown. Northern Madtoms were much more prevalent at this site on 24 July than on 17 July, with a total of 21 madtoms occupying 15 of the 36 nests. Six of the occupied nests contained madtom pairs and one nest contained eggs in addition to a gravid female and a guarding male. The sex of each individual in the madtom pairs was easily determined by dimorphism in size, the presence of secondary sex

characters in the male (flat, broad head and bulging cheeks (Taylor 1969)), and the distended abdomen of the gravid females.

Of the 21 madtoms recorded on 24 July, it was possible to measure the total lengths of all but 2 of the individuals. The mean size was 113.4 mm (± 2.69 S.E.) with the largest individual measuring 129.8 mm total length (TL). This size is close to the maximum of 130 mm reported for the species by Trautman (1981), but Coad (1995) indicated a maximum size of 178 mm. The mean difference in size between male and female *N. stigmosus* was about 20 mm with the females averaging 101.3 mm TL (± 3.62 S.E., $n = 6$) and the males averaging 122.7 mm TL (± 1.97 S.E., $n = 8$). The size ranges for each of the sexes did not overlap.

In each of the three egg-containing nests, the eggs were present as a single mass. The length and width of the egg masses was greater than the thickness with masses being no more than about 5-6 eggs deep at their greatest thickness. The diameters of 25 eggs were measured and the mean was 3.02 mm (± 0.067 S.E., range 2.36-3.73 mm) which falls within the range of other *Noturus* species although data for the genus is limited (Baker and Heins 1994; Pfingsten and Edds 1994). Each of the three clutches contained a minimum of 32, 85, and 140 eggs, respectively. These numbers are somewhat of an underestimate

since on the video it was only possible to count the eggs on the surface of the mass. A conservative estimate of the number of uncounted eggs in the largest mass would be 20 eggs bringing the total up to 160 which exceeds the maximum of 141 eggs reported by Taylor (1969). It is not known if multiple female madtoms will spawn in the nest of a single male, but given the size of the egg mass, particularly of the largest nest, I believe the egg mass represents the spawning efforts of at least two females. In many fishes with male parental care it is common for more than one female to spawn in a single nest (Kraak and Weissing 1996).

Although eggs were only observed in nests on 17 and 24 July, it is likely that spawning occurred over a much longer period since two nests, which did not have eggs present on 24 July, contained larvae 20 days later on 13 August indicating a reproductive season of approximately 2.5 weeks. Additionally, a gravid female was recorded on 13 August suggesting that the reproductive season may be at least one month. The water temperature during this period was 23°C (U.S. Coast Guard weather station, Belle Isle, Michigan). Taylor (1969) collected *N. stigmosus* eggs from mid to late July in Michigan and he also indicated that spawning in Northern Madtoms occurred slightly earlier than in the Brindled Madtom, *N. miurus*. A single Brindled Madtom with larvae was recorded under an artificial nest on August 13, indicating that the spawning seasons of these two species overlap in the upper Detroit River. Unlike the Northern Madtom, the male Brindled Madtom moved out of the nest when disturbed through removal of the artificial nest.

Both larval and juvenile *N. stigmosus* were present in the nests on 13 August and were still being guarded by the male. Three nests contained larvae in different stages of yolk sac absorption and one nest contained juvenile madtoms. Ictalurid catfish young are considered juveniles once the yolk sac has been completely absorbed at which time they have all of their adult fin rays (Tin 1982). It was only possible to measure the size of a few juveniles because as soon as the artificial nest was lifted, the juveniles would take shelter in adjacent macrophytes and also, because of the limited resolution of cryptically coloured larvae in the digitized video image. Of the six juveniles measured, the average TL was 8.7 mm (± 0.28 S.E.). This is similar to the Black and Yellow Bullheads, two ictalurid catfishes with similar egg sizes (Scott and Crossman 1973; Becker 1983). Given the similarity in egg size and juvenile size between the Northern Madtom and the bullheads, the Northern Madtom may have a similar incubation time of 5-10 days. Young-of-the-year (YOY) *N. stigmosus* reached a length of about 30 mm before their first winter based on observations of six individuals that I captured in trawls on 26 October 1996. This length is at the lower end of the size range

reported for YOY Northern Madtom in Ohio by Trautman (1981), but there can be large differences in life history traits exhibited by different populations of the same species (Baker and Heins 1994).

Noturus stigmosus was only known from a single record in Canada and prior to this study, the species was not known to have a reproducing population in Canadian waters. Goodchild (1993) considered the single record of the Northern Madtom from Lake St. Clair in 1963 to be unusual in that it was from atypical habitat for the species. This appears not to be the case since madtoms are reproducing in this same area. Further research into the habitat requirements and preference of *N. stigmosus* is required. Northern Madtoms were regularly captured (up to 7 individuals per 10 minute trawl) while collecting Round Gobies in the upper Detroit River and Lake St. Clair during the summer and fall of 1996 (Figure 1). It is presently unknown what effect the Round Goby has had or may have on the Northern Madtom. Potentially there could be competition for nest sites since both species have similar nest requirements and the Round Goby may prey on eggs and juveniles of the Northern Madtom. Competition for nest sites between the Round Goby and the Mottled Sculpin is the most likely reason for the severe decline of the sculpin populations in the St. Clair River and Grand Calumet Harbour (Lake Michigan) (Jude et al 1995). Further investigation is needed on the interactions between the Northern Madtom and the Round Goby since this is the only known reproducing population of the Northern Madtom in Canada and is at the northern limit of its range (Goodchild 1993). Additional research also is required into the ecological role and life history of this little known species.

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Distribution of Larval Colonies of *Lophocampa argentata* Packard, the Silver Spotted Tiger Moth (Lepidoptera: Arctiidae), in an Old Growth Douglas-fir, *Pseudotsuga menziesii* / Western Hemlock, *Tsuga heterophylla*, Forest Canopy, Cascade Mountains, Washington State

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The distribution of larval colonies of the Silver Spotted Tiger Moth (*Lophocampa argentata* Packard) (Lepidoptera: Arctiidae) was documented in the canopy of a 2.3 ha patch of Douglas-fir/Western Hemlock forest using a 75 meter tall tower crane, in the central Cascade mountains, Washington State, USA. The Silver Spotted Tiger Moth overwinters as larval colonies in tree canopies. Colonies were surveyed 4 December 1995, and 19 December 1996. In 1996 no colonies were present. For each colony, tree species, crown class, crown position and aspect from tree crown were noted. In 1995, 68 colonies were observed on 32 individual codominant trees in the 2.3 ha research area under the jib of the canopy crane. Ten colonies (14.7%) were on Western Hemlock, while 58 (85.3%) were on Douglas-fir, apparently reflecting a preference for Douglas-fir. The colonies were predominantly in the upper crown (> 40 m) areas (87.9%), with some colonies in the mid crown (20–40 m) area (10.3%), and no colonies in the lower crowns (0–20 m). The primary aspects included south (54.4%), southeast (14.7%), and southwest (13.2%), with the apex (5.8%), east (10.3%) and west (1.5%) aspects accounting for all the remaining colonies. No colonies were located on the north, northeast or northwest aspects. These observations suggest that selection of larval colony sites reflects adaptation to exploiting the sunny portion of the tree crown and the portion of the forest which is warmest on sunny days, and this facilitates thermoregulation and winter activity. Additional attributes of thermoregulation in this species are: larvae are dark colored and hairy, build tents, bask in the sun, and aggregate for basking.

Key Words: Silver Spotted Tiger Moth, *Lophocampa argentata*, Douglas-fir, *Pseudotsuga menziesii*, Western Hemlock, *Tsuga heterophylla*, old growth, canopy, Cascade Mountains, Washington.

The Silver Spotted Tiger Moth (SSTM) (*Lophocampa argentata* Packard) (Lepidoptera: Arctiidae) is a defoliator of western conifers that overwinters as larval colonies (Silver 1958) (Figure 1). Adults fly in July and August, females lay eggs in loose clusters, and caterpillars feed in colonies forming loose webs which accumulate dead needles and frass, making them conspicuous (Furniss and Carolin 1977; Johnson and Lyon 1991). Larvae overwinter in colonies and feed gregariously for five, of eight instars. In the spring, larvae disperse and feed individually (Silver 1958; Edwards 1964). The SSTM is considered most important as an insect that detracts from the appearance of specimen trees in parks and urban areas (Johnson and Lyon 1991).

Studies on Vancouver Island, British Columbia, Canada (Silver 1958; Edwards 1964), where the only serious outbreak has been reported, indicate that eggs were laid on the south and west sides of tree crowns, and the larvae feed throughout the winter when weather conditions allow. Edwards (1964) demonstrated that SSTM larvae undergo a temperature-related activity rhythm phase reversal, the

larvae becoming diurnal in the coldest periods of the winter, although nocturnal in the warmer periods of fall and spring.

In April of 1995, a construction tower crane was installed in an old-growth (500 year old) Douglas-fir (*Pseudotsuga menziesii* (Mirbel) Franco.) / Western Hemlock (*Tsuga heterophylla* (Raf.) Sarg.) forest in the T.T. Munger Research Natural Area, Wind River Experimental Forest, located in the central Cascade mountains, Washington State, USA (Latitude N 45° 49' 13.76", Longitude W 121° 57' 06.88"). The facility was developed to provide access to the three dimensions of a tall (60 meter +) forest canopy and to foster research in this habitat. In our initial lifts into the canopy we saw larval colonies of *L. argentata* in the tops of 50 and 60 meter tall Douglas-fir trees (Figure 2). Beginning in September of 1995, we again observed many colonies on Douglas-fir and Western Hemlock. As December approached the colonies became very conspicuous, forming loose webs with small blackish caterpillars that were often closely aggregated (Figure 3).

Although the SSTM is known to occur on old-growth trees (Silver 1958), the distribution of larval colonies within an old-growth forest has never been described. If physical, microenvironmental aspects of the environment are important to development of these winter active colonies, then their distribution within the forest should reflect a particular microhabitat. Microhabitat selection is a basic feature of insect thermoregulation (Casey 1981), while it is particularly important for some caterpillars, especially those that occur in cold environments like the Arctic or are active during colder seasons of the year (Heinrich 1993).

The Eastern Tent Caterpillar (*Malacosoma americanum* Fabricius) has been extensively studied in regard to thermoregulation (Fitzgerald 1995). The colonies are active early in the spring when ambient temperatures are below the minimum temperature required for growth. A combination of factors assists the caterpillars in thermoregulating, including direct exposure to sunlight, aggregation of individuals, and tent building (Fitzgerald 1995). Basking in sunlight elevates individual caterpillar temperature, while aggregation aids this by reducing loss of convective heat. The tent again aids in thermoregulation because of the boundary layer created by the tent also reduces convective heat loss. Exposure to the radiant heat of sunlight is necessary for this thermoregulation (Fitzgerald 1995).

The SSTM exhibit similar behavioral and physical attributes of the eastern tent caterpillar: caterpillars are hairy and dark colored (Figure 1), the larval colonies are active in the colder portion of the year, build tents (Figure 2), and aggregate to bask in sunlight (Figure 3). To accommodate thermoregulation, however, they must be exposed to the sun.

Tall stature, old-growth Douglas-fir/Western Hemlock forests have complex structure (Franklin et al. 1981), with a very well-developed vertical component. Parker (1997) has quantified the vertical structure and light environment of the forest under the canopy crane. Although some trees exceed 60 meters in height, the highest abundance of foliage is between 10 and 20 meters, with over 75% of the total stand foliage below 30 meters. Parker (1997) defined three light zones; a bright zone above 40 meters where transmittance exceeds 80% of the possible full light; a transition zone from 40 meters to 12 meters where the light transmittance steeply declines to about 10% of the possible full light; and a dim zone below 12 meters where the light transmittance is below 10% of full light. If sunlight is important in the development of the SSTM, then we would expect the larval colonies to be distributed in the bright zone of the forest and on the generally southern side of tree crowns.

I report here on the results of a survey of the distribution of larval colonies within reach of the canopy crane on 4 December 1995. The area was

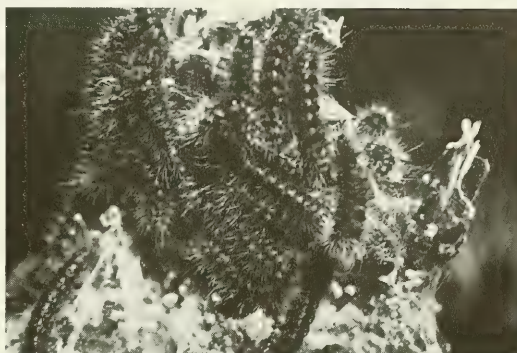


FIGURE 1. Larvae of *Lophocampa argentata*, the Silver Spotted Tiger Moth, March 1996. Note the initial development of setal tufts on the dorsal abdominal segments, these setal tufts become well developed in later instars.

resurveyed on 19 December 1996, but no colonies were observed.

Study Site and Methods

The study site is located in the Thornton T. Munger Research Natural Area, a 478 hectare old-growth Douglas-fir/Western Hemlock forest within the Wind River Experimental Forest, Gifford Pinchot National Forest, Washington State, USA. Elevation is 355 meters, and precipitation averages 2528 millimeters, with June, July and August precipitation averaging 119 millimeters. Average annual temperature is 8.7°, with January average temperature of 0°. Average snow fall is 233 centimeters.

Tree abundance, based on trees greater than 5 cm diameter at breast height from a four hectare research plot around the canopy crane, is: Western Hemlock 230 trees/ha, Pacific Yew (*Taxus brevifo-*

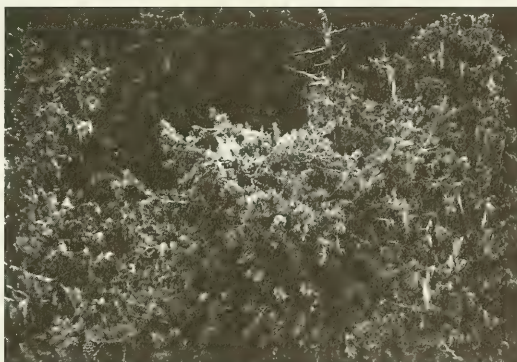


FIGURE 2. Tent and feeding damage from a larval colony of *Lophocampa argentata* in the top of a 50 meter Douglas-fir tree, April 1995.

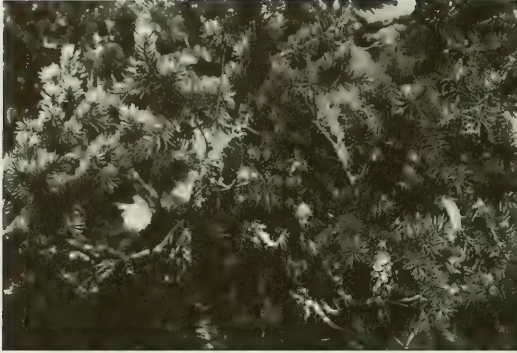


FIGURE 3. Larval aggregation of *Lophocampa argentata* on the upper and sunny south side of a co-dominant Douglas-fir tree crown, March 1996. Note how tightly aggregated the sun basking larvae are.

lia Nutt.) 90 trees/ha, Amabilis Fir (*Abies amabilis* (Dougl.) Forbes) 48 trees/ha, Douglas-fir 38 trees/ha, Western Redcedar (*Thuja plicata* Donn.) 30 trees/ha, Grand Fir (*Abies grandis* (Dougl.) Forbes) 5 trees/ha, and Noble Fir (*Abies procera* Rehder) 0.25 trees/ha. However, trees greater than 40 meters in height were: Douglas-fir 33 trees/ha, Western Hemlock 32 trees/ha, Western Red Cedar 11 trees/ha, Grand Fir 2.5 trees/ha, Amabilis Fir 0.75 trees/ha, and Noble Fir 0.25 trees/ha. Pacific Yew rarely exceeds 12 meters in height.

Individual colonies of the SSTM were easily identifiable by the clusters of old webbing and the dead leaves associated with it. The caterpillars were not necessarily in the old webbing areas, but usually nearby (within 1m). The Wind River Canopy Crane is 75 meters tall, with an access arm (jib) 85 meters long, reaching 2.3 ha of old-growth Douglas-fir/Western Hemlock forest. The dominant and codominant trees are generally well spaced so that each crown can be individually inspected from a gondola suspended from the jib.

Colonies were surveyed on 4 December 1995 during cool clear weather. Clear weather was needed to make observations easier, and use of the crane safer. The site was surveyed from the gondola by two people, one person observing crowns and using binoculars when necessary, while the other took notes, observed crowns, and communicated with the crane operator. The site was divided into spokes of a wheel, using compass directions; 0, 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330, totaling twelve spokes. The survey area for each spoke was narrow near the tower and enlarged further from the tower. The crane provides the opportunity to sample the entire canopy under the jib, so there was no need to subsample, as all colonies were accessed.

Colonies were surveyed as the gondola was moved slowly along a given spoke. The crane oper-

ator attempted to keep the gondola near the surface of the canopy and drop into gaps as they were approached. When questionable colonies were observed we went directly to the colony area to determine if indeed it was SSTM.

For each colony tree species, crown class of the tree, crown position of the colony, aspect of the colony in relation to the crown it was in, and spoke number were noted. Crown classes were divided into dominant, codominant, intermediate and understory. Crown position of the colony was divided into upper = 40 m to 65 m, mid = 20 m to 40 m, and lower = 0 m to 20 m. The aspect the colony faced in relation to the tree crown was noted as north, northeast, northwest, south, southeast, southwest, east, west, or apex of the tree.

Results

Sixty-eight colonies on 32 trees, were observed in the 2.3 ha research area under the jib of the canopy crane. Ten colonies (14.7%) were on Western Hemlock, while 58 (85.3%) were on Douglas-fir. The colonies were predominantly in the upper crown areas (87.9%), with some colonies in the mid crown area (10.3%), and no colonies in the lower crowns. The primary aspects included south (54.4%), southeast (14.7%), and southwest (13.2%), with the apex (5.8%), east (10.3%) and west (1.5%) aspects accounting for all the remaining colonies. No colonies were located on the north, northeast or northwest aspects. All trees were codominant or dominant crown class.

Douglas-fir represents 41.4 % of trees in the upper canopy (greater than 40 meters in height), while Western Hemlock represents 40.2 %, Western Redcedar 14 % and Grand Fir 3.1%. Colonies were found only on Douglas-fir (85.3%) and Western Hemlock (14.7%). In this habitat, SSTM appears to prefer Douglas-fir, and then secondarily Western Hemlock. However, of trees greater than or equal to 55 meters in height, the percent of Douglas-fir (88.5%) versus Western Hemlock (11.5%) is very similar to the host choice percentage.

Discussion

Colonies of the SSTM occur in the upper canopy (bright zone) and on southerly aspects of tree crowns, within this tall (> 60m) old-growth forest stand during fall and winter. This suggests a preference for the sunniest locations in the forest, because light levels drop off significantly below 40 meters (Parker 1997), and the north side of trees crowns are shaded. Silver (1958) observed SSTM females laying eggs preferentially on the south and west sides of Douglas-fir tree crowns on Vancouver Island, British Columbia. I did not observe egg laying, and therefore cannot state whether the locations of larval colonies represents ovipositional sites.

The upper canopy is the active layer for heat exchange (Parker 1995), and during mid-afternoon, on sunny days, the upper canopy becomes the warmest location in the vertical forest profile (Geiger 1965; Parker 1995). Therefore, in addition to a preference for the sunniest location in the forest, the colony sites are in an area that becomes the hottest region of the forest on any given sunny midafternoon.

The SSTM is an active thermoregulator, with physical and behavioral adaptations to deal with the cold environment of fall, winter and spring. The larvae are dark-colored and hairy (Figure 1), build tents (Figure 2), bask in the sun, aggregate for basking (Figure 3), and locate larval colonies in sunny sites, all of these features are considered important for thermoregulating caterpillars (Fitzgerald 1995). In addition, the SSTM exhibits a temperature-related phase reversal, where the larvae are active in the daytime during the colder portion of the year, and become nighttime active when temperatures warm up (Edwards 1964). Edwards (1964) demonstrated with laboratory studies that caterpillars were exclusively daytime feeders when temperatures were held constant at 5°C, had no set pattern at 10°C, and were nighttime feeders at 23°C.

Fitzgerald (1995) and others (in Fitzgerald 1995) theorize that the Eastern Tent Caterpillar has adapted for thermoregulation during colder weather in early spring to avoid predation. I hypothesize that the SSTM has adapted to thermoregulate in winter to avoid predation also. The SSTM becomes nocturnal when temperatures allow, usually in fall and spring, and is active during the daytime only when temperatures are low. This would avoid avian predators when they are more abundant in spring and fall. Avian species diversity and abundance drops off significantly during winter at the Wind River Canopy Crane Research Facility: average number of bird species observed during weekly morning surveys were; spring 17, summer 17, fall 9, and winter 4 (D. Shaw and C. Flick, unpublished data). Also, the caterpillars do not develop significant setal tufts, which are highly irritating to the skin when handled, until later instars (Silver 1958), which would aid predation defense in the spring.

Host choice for larval colonies of SSTM appears to reflect a general preference for Douglas-fir, secondary preference for Western Hemlock, and avoidance of Western Redcedar. Initial studies at the wind river canopy crane site indicate Western Redcedar experiences almost no herbivory (Shaw and Baker 1996). Other tree species may be too low in number in the upper canopy. When considering trees greater than or equal to 55 meters in height, Douglas-fir and Western Hemlock (88.5%/11.5%) occur in similar

proportions to the occurrence of larval colonies (85.3%/14.7%). A 55 meter tall tree has 15 meters of crown exposed to the sunlight in the bright zone. It is possible that there is no preference for Douglas-fir per se, but that Douglas-fir has more crown surface area in the bright zone where SSTM larval colonies find suitable microhabitat.

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White-tailed Deer, *Odocoileus virginianus*, Capture Techniques in Yarding and Non-yarding Populations in New Brunswick

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During 1994-1996 we captured and radiocollared fawn (6-9 months old) and adult White-tailed Deer (*Odocoileus virginianus*) in yarding and non-yarding populations in New Brunswick using Clover trapping, darting from tree stands, rocket netting, and helicopter net gunning. With the exception of net gunning, we immobilized 81 deer with a combination of ketamine HCL and xylazine HCL. We antagonized chemical immobilizations by administering 10-27.5 mg yohimbine hydrochloride. Forty-eight deer were captured in Clover traps from which seven escaped. Ninety-two deer were captured in both study areas; 19 in the non-yarding population and 73 in the yarding population. Ground capture methods were effective in the yarding population but not in the non-yarding population where capture rates were lower apparently because deer were not attracted to baits. Forty-three deer were captured and radiocollared by helicopter net gunning using 16.5 hours of helicopter time. Several methods were used to locate neonate fawns. Methods included monitoring radiocollared doe movements and behavior, checks of open fields, night-lighting, intensive ground grid searches, and opportunistically. Of these, only intensive ground searching was effective (35 of 50 captures) and required an average of 30.6 person-hours per fawn captured.

Key Words: White-tailed Deer, *Odocoileus virginianus*, capture methods, fawns, immobilization, ketamine hydrochloride, Telazol®, xylazine hydrochloride, yohimbine hydrochloride, New Brunswick.

Adult and fawn (6-9 months-of-age) deer (*Odocoileus* spp.) have routinely been captured for radiocollaring with Clover traps, box traps, corral traps, cannon or rocket nets, drive nets, net guns, snares, and drugs (Rongstad and McNabe 1984). Neonates (<1 month old) have been located for hand-capture by systematic searches on foot or horse back (Bolte et al. 1970; Logan 1972; Lund 1975; Bryan 1980; Schultz 1982), observations of nursing does (Downing and McGinnes 1969; White et al. 1972; Garner et al. 1976; Bartush and Lewis 1978), vaginal transmitters inserted in pregnant does (Giessman and Dalton 1981*; Temple 1981*), tape-recorded fawn distress calls (Arthur et al. 1978), and more recently, by changes in behavior of radiocollared does (Huegel et al. 1985). All of these methods have advantages and disadvantages.

Beginning in 1994 we initiated two deer studies in New Brunswick to investigate population dynamics and habitat use of yarding (northern) and non-yarding (southern) populations of White-tailed Deer

(*Odocoileus virginianus*). We sought to capture deer with the most efficient and cost-effective methods available. We selected Clover traps for capture with a combination of ketamine hydrochloride (KET) and xylazine hydrochloride (XYL) for immobilization of deer (≥ 6 months of age). We initially attempted to locate neonate fawns for radiocollaring by changes in radiocollared doe behavior as described by Huegel et al. (1985). We encountered a number of problems with these methods and either had to make modifications to equipment or test other methods in order to capture deer successfully. The purpose of this paper is to assess the efficiency of methods for capturing deer in a yarding and non-yarding population in New Brunswick.

Study Area

White-tailed Deer were caught in northern (Odell Deer Yard; 46°N, 67°E) and southern (Canaan; 45°N, 64°W) New Brunswick, Canada. The Odell Deer Yard was privately owned by Fraser Papers, Inc. Its management does not fall under Provincial guidelines, and has had moderate forestry interventions since the 1950s. The 1690-ha deer yard has

*See Documents Cited section.

diverse habitat, and an extensive road-trail network. Approximately 60% of the yard is considered critical deer winter habitat consisting of a dense (60–70%) overstory of White Spruce (*Picea glauca*), Eastern Hemlock (*Thuja occidentalis*) and Balsam Fir (*Abies balsamea*) (Anonymous 1995). The remainder has interspersed small openings (<3 ha) and skidder trails from logging operations, with a hardwood overstory of Balsam Poplar (*Populus balsamifera*) and White Birch (*Betula papyrifera*). The Canaan study site (757 km²) was in the northern part of the Fundy Model Forest, and was divided into two distinct regions. The northern section consisted mainly of Crown Lands and large private holdings subject to intensive forest management, which resulted in a pattern of large (e.g., 20–100 ha) openings and a scarcity of mature conifer stands. Topography was flat, and forest cover was composed of mature stands of Trembling Aspen (*Populus tremuloides*), Largetooth Aspen (*Populus grandidentata*), Red Maple (*Acer rubrum*), and White Birch and young plantations of Black Spruce (*Picea mariana*) and Jack Pine (*Pinus banksiana*). The southern section consisted of small private woodlots and farms. Topography was hilly, and forest cover consisted primarily of mature Sugar Maple (*Acer saccharum*) and Yellow Birch (*Betula alleghaniensis*) on hills, and mature Red Spruce (*Picea rubens*), White Spruce, Eastern White Cedar (*Thuja occidentalis*), and Trembling Aspen on lower elevations. Timber harvest patterns in small woodlots resulted in small, irregular clearcuts (<20 ha) and partial cuts.

Deer have used the Odell Deer Yard since the 1950s. Winter densities in the Odell yard were estimated at 12/km², using a modification of Potvin et al. (1992) aerial double count method (Ballard et al. 1996*). Assuming that deer yards represent 10–15% of the summer range area (Broadfoot et al. 1996), with a productivity of approximately 1 fawn/adult doe in northern New Brunswick (J. Dempsey, New Brunswick Department of Natural Resources and Energy, Fredericton, New Brunswick, personal communication), we estimated summer deer density at 2–3 deer/km². Winter deer densities at Canaan were variable and ranged from 3 to 22 deer/km² depending upon winter severity while summer densities averaged 8/km².

Methods

We initially utilized Clover (1954, 1956) traps as modified by McCullough (1975) to capture deer (≥6 month old) January–April 1994–1996 except that instead of knotless No. 84 nylon twine 145.2 kg test netting with 10.2 cm square mesh, we utilized knotted 3 mm polyethylene with 12.7 cm square (25.4 cm stretch) 130 kg test netting. Because seven deer broke through the netting it was replaced with

knotted 3 mm polyethylene 5 cm square (10 cm stretch) 130 kg test netting (I. M. P. Group Limited, Dartmouth, Nova Scotia). This modification alleviated deer breaking through the net, but other complications arose. Welds as described by McCullough (1975) for end frames broke when adult deer were captured at the -10 to -35°C temperatures in our study areas. We subsequently used nuts and bolts for all connections. After the aforementioned problems were alleviated, adult deer apparently used their snouts to open trap doors allowing several deer to escape. This problem was solved by drilling holes in the steel conduit pipe at the bottom of the door and bolting in U-clamps. Holes were also drilled at the bottom of the frame and wire was inserted and secured, and bent downwards. The hanging U-clamps allowed the door gates to slide down but not up without pressuring the clips and successfully retained captured deer. Following these modifications the traps generally operated as expected.

We used salt, apples, alfalfa, and Eastern White Cedar (*Thuja occidentalis*) for bait, but only Cedar consistently attracted deer in our study areas. We monitored each Clover trap twice daily by means of trap transmitters similar to procedures described by Hayes (1982). Although we modified the position of baits and trap door position on Clover traps as suggested by Garrott and White (1982), the traps captured a high proportion of fawns. We also attempted to capture deer in both study areas with rocket nets (Rongstad and McNabe 1984) and began darting from tree stands over Cedar bait to capture adults during December–April 1993–94 through 1995–96.

We restrained trapped deer and injected them intramuscularly (IM) with 250–700 mg KET and 70–200 mg XYL depending on deer age and state of immobilization. Darted deer were injected with 600–1000 mg KET and 100–450 mg XYL depending on age and state of immobilization. Following processing, each deer was injected with 10–27.5 mg yohimbine hydrochloride (YOH) to antagonize immobilization.

During winter 1995 several adult darted deer did not become immobilized with the KET-XYL dosages we used. Consequently, we began darting deer with a combination of tiletamine HCL and zolazepam HCL (Telazol® mixed with distilled water at 100 mg/ml, Fort Dodge Laboratories, Inc., Fort Dodge, Iowa 50501), and XYL. A total of 650–750 mg Telazol® and 100–174 mg XYL was used to immobilize adult deer. Similar to KET-XYL injections, immobilization was antagonized by IM injection of 16–25 mg YOH.

We defined induction time as the period from when the drug was delivered to when immobilization was satisfactory to allow processing. Recovery time was defined as the time period from when YOH was injected until the animal left the capture site.

Each immobilized deer was restrained, blind-folded, sexed, aged according to tooth wear and replacement, ear-tagged, blood sampled, weighed, and fitted with radio-collars (Lotek Engineering, Newmarket, Ontario). Deer condition was subjectively evaluated as 1 = poor, 2 = fair, 3 = good, and 4 = excellent based upon physical examination similar to criteria utilized on Moose (*Alces alces*) by Franzmann (1977). Fawn (≥ 6 months old) radiocollars were similar to those described by Garrott et al. (1985) and remained on the animals an average of 302 ± 92 days ($n = 5$). Each transmitter contained a motion sensor which signaled after a 4-hour period when either a mortality occurred or the transmitter had fallen off. All deer were monitored once daily during the first month post-capture and then once per week for the remainder of the study.

During late winter 1995 we contracted Helicopter Wildlife Management (4670 South Fortuna Way, Salt Lake City, Utah 84124) to capture deer in the southern study area by net gunning from helicopter, similar to methods described by Krausman et al. (1985). Captured deer were restrained, blind-folded, blood sampled, aged by tooth-wear and replacement, radiocollared, and released.

Several methods were used to locate neonate deer fawns for radiocollaring during June 1994-1996. Originally, we attempted to locate fawns by monitoring changes in radiocollared doe behavior as described by Huegel et al. (1985). When this method did not produce results we tried night-lighting along logging roads, checking open fields at dawn and dusk, and intensive ground searches of flood-plain and adjacent habitats. When fawns were located they were sexed, and fitted with expandable, break-away radio-collars (Lotek and Telonics, Mesa, Arizona) similar to those described by Kester et al. (1988). As with the adult transmitters, each transmitter contained a motion sensor that either doubled or halved the pulse rate of the radio signal when the transmitter remained motionless for a 4-hour period. Neonate fawn signals were monitored daily through summer and then once per week until transmitters fell off. Transmitters remained on neonates an average of 263 ± 121 days.

We compared trap nights or person-hours of effort in relation to deer captured by capture method by 2×2 Chi-square contingency analyses. Differences in average values were compared by ANOVA. For many comparisons sample sizes were either unbalanced or small and consequently our power to detect significant statistical differences was low. Differences were considered significant at $P \leq 0.05$. Means are reported with standard deviations. All capture and protocol methods were approved by the University of New Brunswick Animal Care Committee.

Results

Fawns and adults — A total of 1517 trap nights effort was expended trapping 48 deer with modified Clover traps; 45 in the northern study area and 3 in the southern study area (Table 1). Trap nights per deer captured averaged 22.8 and 163.0 for northern and southern areas, respectively. There were significant differences in the numbers of deer caught among years in the northern study area ($\chi^2 = 19.5$, $P < 0.05$); proportionately more deer were captured in the northern study during 1994 ($\chi^2 = 9.6$, $P = 0.002$) and 1996 ($\chi^2 = 12.1$, $P = 0.001$) than during 1995. There were no differences in proportions of deer caught between 1994 and 1995 ($\chi^2 = 1.8$, $P = 0.18$) in the southern area, but overall fewer were caught in the southern area than in the northern area (north area 1994 and 1996 pooled versus southern area [$\chi^2 = 25.0$, $P = 0.001$] and north 1995 versus southern area [$\chi^2 = 4.3$, $P = 0.04$]). There were no differences between sex ratios of trapped fawn ($\chi^2 = 0.3$, $P = 0.56$) and adult ($\chi^2 = 2.3$, $P = 0.13$) deer but proportionately more fawns than adults were captured ($\chi^2 = 6.7$, $P = 0.009$).

A total of 934 person-hours was spent in tree stands attempting to dart deer (Table 1). Hours in tree stands per deer captured averaged 16.4 and 24.0 for north and south study areas, respectively. There were no differences in the proportions of deer caught in relation to capture effort among years in both the northern (χ^2 range = 0.2-0.6, $P = 0.44 - 0.66$) and southern areas ($\chi^2 = 3.1$, $P = 0.08$) nor between study areas ($\chi^2 = 1.5$, $P = 0.23$).

We also expended 207 person-hours of effort attempting to rocket net deer in both study areas (Table 1) but these efforts were curtailed because of poor capture success (i.e., 1 deer per 207 person-hours effort) and the number of people necessary to operate the nets.

A total of 91 deer was either captured in Clover traps and immobilized, or darted from tree stands and immobilized during 1994-1996 in both study areas; 73 deer in the northern area and 18 in the southern area. After Clover traps were modified as described within the methods section, no deer escaped. Forty-one deer were successfully trapped and immobilized with KET-XYL and 41 were successfully darted with KET-XYL. Ketamine HCL-xylazine HCL dosages for trapped deer averaged 12.3-3.4, 9.6-2.6, and 8.4-2.3 mg/kg of body mass for fawn (≥ 6 months age), yearling, and adults, respectively, while dosages for darted deer averaged 20.4-4.6, 18.2-3.1, and 11.6-2.4 mg/kg body mass for fawn, yearling, and adult deer, respectively. Antagonist (YOH) dosages ranged from 0.25 to 1.1 mg/kg body mass. Two fawns died as a result of the capture process in the northern study area; one fawn was in poor condition and died of unknown

TABLE 1. Capture effort and numbers of White-tailed Deer captured by several capture methods during December-April 1994-96 in yarding (northern) and non-yarding (southern) populations in New Brunswick.

Study Area	Year	Method:			Clover traps			Darting			Rocket net			Helicopter net gunning		
		Trap nights	Deer	Rate	Person-hours	Deer	Rate	Person-hours	Deer	Rate	Person-hours	Deer	Rate	Person-hours	Deer	Rate
Yarding	1993-94	397	24 ^a	15.8	165	12	13.4	90	0	0.0						
	1994-95	553	12	46.1	303	18	16.8									
	1995-96	96	9	10.7	106	5	21.2									
Non-yarding	\bar{x} or sub-total	1046	45	22.8	574	35	16.4	90	0	0.0						
	1993-94	150	2	75.0	246	7	35.1	105	0	0.0						
	1994-95	339	1	339	114	8	14.3	12	1	12.0				49.5 ^b	43	1.2
	\bar{x} or sub-total	489	3	163	360	15	24.0	117	1	117.0				49.5	43	1.2

^a Seven deer escaped and were not immobilized.

^b Helicopter hours = 16.5

causes, and one died as a result of physical injury from the dart. No other capture-related mortalities occurred in either study area.

Induction times for northern deer fawns (sexes pooled) immobilized with KET-XYL averaged 7.4 ± 3.3 and 32.8 ± 8.2 minutes for trapped and darted deer, respectively, while induction times for adult females averaged 7.0 ± 3.5 and 44.0 ± 29.8 minutes, respectively for trapped and darted deer. Induction times were significantly greater for darted versus trapped deer ($F = 20.5$, $P = 0.0001$). Recovery times for northern fawn and adult deer reversed with YOH averaged 36.9 ± 39.8 minutes and were not significantly different by age ($F = 0.75$, $P = 0.39$), capture method ($F = 0.12$, $P = 0.73$), or their interaction ($F = 0.06$, $P = 0.81$). Recovery times for adult female deer in southern areas averaged 52.6 ± 15.3 minutes.

A total of eight adult deer escaped after being darted with KET-XYL; four in the northern study area and four in the southern area. We suspected that the KET-XYL dosages were insufficient to immobilize deer in good to excellent condition. In the northern study area there was no significant difference in physical condition at time of capture between fawn and adult female deer ($F = 1.4$, $P = 0.24$), but darted deer were in significantly better condition than those that were trapped ($F = 5.1$, $P = 0.03$). Darted deer had significantly higher ($P = 0.01$) condition indices than deer caught in traps.

Following the escape of several deer which had been darted with KET-XYL, we began using a combination of Telazol® and XYL to dart adult deer. A total of nine adult deer (six in the north and three in the south) were immobilized with 650–750 mg of Telazol® and 100–174 mg XYL. Telazol® dosages averaged 10.7 ± 2.3 mg/kg of body mass while XYL dosages averaged 1.7 ± 0.33 mg/kg of body mass. Induction times averaged 28.5 ± 16.6 minutes. An attempt was made to reverse immobilization by injecting an average YOH dosage of 0.35 ± 0.07 mg/kg of body mass. Recovery times averaged 70.4 ± 108 minutes and condition indices averaged 2.8 ± 0.8 .

Because relatively few deer were captured and immobilized within the southern area during March 1995 we attempted to capture deer by helicopter net-gunning (Table 1). A total of 43 yearling and adult deer were captured and radiocollared with 16.5 hours of helicopter effort or 49.5 person-hours effort. Deer were captured as they were encountered and proportionately more females ($n = 35$) than males ($n = 8$) were captured ($\chi^2 = 9.5$, $P = 0.002$). No capture-related mortalities occurred during or after the capture process.

Neonates — A total of 1344 person-hours were expended attempting to locate and capture neonate deer fawns (Table 2). We monitored behavior and movements of radiocollared does during parturition

TABLE 2. Capture effort and number of neonate White-tailed Deer fawns captured and radiocollared in northern (yarding) New Brunswick during June 1994-96.

Year	Monitoring radiocollared does						Field checks			Night-lighting			Ground grid search			Opportunistic		
	Person-hours	Deer	Rate	Person-hours	Deer	Rate	Person-hours	Deer	Rate	Person-hours	Deer	Rate	Person-hours	Deer	Rate	Person-hours	Deer	Rate
1994	54	0	0	130	2	65	48	1	48	310	8	38.8	?	?	?	?	3	
1995	0			30	3	10	0	0		475	11	43.2	?	?	?	?	2	
1996	0			12	1	12	0	0		285	16	17.8	?	?	?	?	3	
Total or \bar{x}	54	0	0	172	6	28.7	48	1	48	1070	35	30.6	?	?	?	?	8	

1994 but located no fawns and discontinued this method. We also attempted night-lighting along logging roads during 1994 and only located one fawn during 48 person-hours of effort. The latter method was also discontinued after 1994. We expended 172 person-hours checking open fields at dawn and dusk and captured six fawns during 1994-1996. Proportionately more fawns were captured by checking open fields during 1995 than during 1994 ($\chi^2 = 5.2$, $P = 0.02$) but not between 1994 and 1996 ($\chi^2 = 2.2$, $P = 0.14$). There was no difference in the proportions caught between 1995 and 1996 ($\chi^2 = 0.02$, $P = 0.88$). Opportunistic efforts resulted in the capture of eight neonates during the three years. Although field checks appeared to be an effective method of locating fawns, opportunities were limited by the numbers of fields available.

The most time-effective method we used to locate neonate fawns was grid-searching likely habitats (Table 2). A total of 35 fawns was located during 1070 person-hours of search effort during the three summers ($\bar{x} = 30.6$ hours per fawn captured). Crew size each year of capture averaged 8.9 (range = 5-12), 6.6 (range = 4-10), and 6.0 (range = 1-9) individuals during 1994, 1995, and 1996, respectively. There were no differences in the proportions of fawns captured in relation to capture effort between 1994 and 1995 ($\chi^2 = 0.1$, $P = 0.82$) or between 1994 and 1996 ($\chi^2 = 3.3$, $P = 0.07$) but proportionately more fawns were captured in 1996 than in 1995 ($\chi^2 = 5.2$, $P = 0.02$). Sex ratios (32 F: 16 M) of all captured neonates appeared to be skewed in favor of females but differences were not significantly different from 50:50 ($\chi^2 = 2.7$, $P = 0.10$). Only one set of twin fawns was captured. No fawns were abandoned as a result of capture efforts.

During 1994, two fawns kicked off their collars. During 1995 we observed five neonates fall to the ground and immediately begin kicking at the collar with their hind legs in an apparent effort to remove the collar. Although two fawns successfully kicked off the collars, one was recaptured and recollared. Ultimately five fawns kicked off their collars during 1995. During 1996, 11 fawns attempted to kick off their collars and four did so successfully but three were recollared. During 1996, our improved success in keeping collars on neonates was a result of the fact that we forced fawns into submissive posture by pushing them tightly into the ground and controlling their leg movements. This procedure appeared to calm the fawns after which they were slowly released. Following this procedure, no fawns removed their collars.

Discussion

The relatively low deer capture rate with Clover traps in the non-yarding (southern) deer population

was directly related to our inability to attract deer with bait because deer were probably less food-stressed than the northern, yarded deer. Winters in southern New Brunswick are relatively mild in relation to northern New Brunswick due to thin snow cover and fewer days below -15 degrees C (unpublished data). Consequently, northern yarded deer were more food-stressed, as evidenced by condition indices at the time of capture, and therefore more susceptible to being baited than southern deer.

Garrott and White (1982) indicated that the sex and age class of Mule Deer captured in Clover traps could be influenced by changing the height of trap doors and by bait placement. We frequently manipulated these variables but consistently caught high proportions of fawns. This result forced us to examine other capture methods for capturing adult deer.

Baiting with Eastern White Cedar and darting from tree stands was our most effective method of capturing adult deer in the yarding (northern) population. It was also the most effective method in the non-yarding population prior to the use of helicopter net gunning. However, only 2 of 15 deer were actually attracted to bait and our capture methods were totally dependent on White Cedar cutting operations which did attract Deer but were only available once in 1994 and once in 1995, and were beyond our control for Deer capture. Although rocket netting appeared to have potential for capturing large numbers of adult deer, deer captured by this method often have high rates of mortality due to capture myopathy (Berringer et al. 1996). Also, our inability to attract large numbers of deer to bait in the southern area, and relatively high time requirements (i.e., 207 person-hours per deer captured) made this method of capture unfeasible for this study.

Jessup et al. (1983) reported that they successfully immobilized (83% effectiveness) Mule Deer (*Odocoileus hemionus*) with KET dosages of 5.8–14.5 mg/kg of body mass and XYL dosages of 0.44–0.92 mg/kg body mass. Recumbency was achieved within an average of 9.5 minutes. Immobilizations were reversed with 0.125 mg of YOH/kg body mass administered intravenously (IV). Recovery time for seven deer averaged 8.2 minutes but three deer required 20 to 30 minutes to become ambulatory. Mech et al. (1985) reported that captive yearling and adult White-tailed Deer were immobilized with 3.78–14.77 and 0.54–1.99 mg/kg of body mass of KET and XYL, respectively but that an additional 600 mg KET was often necessary for effective immobilization. Induction occurred within 2–35 minutes after the drugs were administered. Immobilizations were reversed with 5–30 mg YOH delivered IV and recovery took an average of 20 minutes. Wallingford et al. (1996) immobilized captive and wild White-tailed Deer with dosages of 1.1–2.2 and 1.8–4.4 mg/kg body mass of KET and

XYL, respectively and antagonized immobilization with 0.4 mg/kg body mass of YOH. Recovery averaged 9.7 minutes. KET and XYL dosages utilized in our study were relatively high in comparison to those previously reported for deer. We suspect that the higher dosages were necessary because of excitation caused by the capture process, and because darted deer were in relatively good condition based upon condition indices. Also, induction times were longer than those previously reported in spite of relatively higher dosages of KET-XYL. Antagonist dosages were similar to those previously reported (Wallingford et al. 1996), but recovery times were longer in part, because of the higher KET-XYL dosages and because the antagonist was administered IM rather than IV.

Several adult deer which were darted with the KET-XYL combination were not successfully immobilized, and escaped. A number of explanations exist for failure of immobilization. First, the dart may have malfunctioned and the animal would have received partial dosage or no drugs. Secondly, except during the severe winter of 1994, deer were in good to excellent physical condition, particularly in the non-yarding (southern) population. Total drug volumes of KET-XYL approached 10 ml. Ten ml darts have a relatively low effective delivery range and we were unwilling to use 15 ml darts to accommodate higher KET-XYL volumes because of their even more limited shooting range. Consequently, we used a combination of Telazol® (650–750 mg @ 100 mg/ml) and XYL (100–174 mg) to immobilize adult deer. Nine adults were successfully immobilized with an average induction of 29 minutes (range = 1–51 minutes). However, recovery times were relatively long, averaging 70 ± 108 minutes ($n = 5$), but when one deer which recovered within 255 minutes was excluded from the analysis, recovery times ($0 = 24$ minutes) were less than those for deer immobilized with KET-XYL. Telazol®-XYL combination appeared to be an effective alternative to KET-XYL, particularly for immobilizing adult deer in good to excellent condition.

Capture success (both Clover-trapped and darted deer) was lower in the non-yarding than in the yarding deer population. Only 19 deer were captured in the non-yarding population in comparison to 100 in the yarding population. Our inability to attract large numbers of deer to bait greatly affected our ability to capture deer with ground based methods.

Although the helicopter capture procedure was quick and cost-effective it was not considered practical at the beginning of this study, in part, because it required an up-front cash expenditure. It was administratively easier and politically expedient to allocate people and equipment resources to less effective ground capture methods. Clearly, our results indicate that in a non-yarding White-tailed Deer population

helicopter net-gunning was an effective capture method. We recommend this capture method when large sample sizes of radiocollared deer are required to achieve project objectives.

We attributed our failure to locate neonates by observing radiocollared does to several factors. First, Huegal et al. (1985) reported that parturient does were reluctant to leave 1–10 day-old-fawns. However, in this study radiocollared does always fled and were rarely observed. Both Ozoga et al. (1982) and Schwede et al. (1994) observed that following parturition, captive White-tailed Deer dams associated very little with their fawns and that contact periods were brief. These observations appear to contradict Huegal et al.'s (1985) observations and suggest that doe-fawn relationships post-parturition may vary over geographic areas. Secondly, Huegal et al.'s (1985) study area was largely composed of agricultural farmlands presumably with low predator populations, whereas our study area was largely forested interspersed with small pastures and was occupied by several predator species. Perhaps these factors also influence doe-fawn relationships.

Our most effective method of locating neonate deer fawns for capture was ground grid searching. Although not statistically different, our efficiency in locating fawns appeared to increase each year of study as we learned where fawns were likely to occur.

Although ground grid searching was an effective method for locating neonate fawns this method probably greatly underestimates twinning rates. During this study only one set of twins was located and radiocollared. Ozoga et al. (1982) reported that distance between siblings within two weeks of parturition averaged 162 m. Our capture method included such distances suggesting that fawn sightability was low.

In summary, use of Clover traps and darting from tree stands using KET-XYL for immobilization appeared to be effective for capturing fawn (≥ 7 mos. old) and adult deer in a yarding population but not in a non-yarding population. A combination of Telazol®-XYL appeared suitable for deer immobilization, particularly when KET-XYL volumes became excessive for effective shooting with a dart gun. Helicopter net gunning appeared to be the most effective method for capturing yearling and adult deer in a non-yarding population. Doe-fawn relationships following parturition may vary by geographic area, habitat types, and predator species density and composition. A variety of methods should be utilized to locate neonate fawns for capture in northern latitudes until success is achieved. In this study, intensive ground grid searching was the most effective method for locating neonate deer fawns.

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Summer Diet of Gray Wolves, *Canis lupus*, in Northwestern Alaska

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In northwestern Alaska where Caribou (*Rangifer tarandus*) migrate out of the area for the summer we determined the 1988–1990 summer diets of Gray Wolves by analyzing 1182 scats collected from nine packs. The number of prey items per scat ranged from 1.1 to 1.9 ($\bar{X} = 1.4$). Caribou, Moose (*Alces alces*), microtines, and birds, primarily Ptarmigan (*Lagopus* spp.), composed 47, 22, 11, and 14% of prey items, respectively. Ungulates composed 90%, birds 7%, and microtines 0.5% of biomass consumed. Ungulates composed 3%, birds 50%, and microtines 39% of numbers of individuals consumed. The number of individual Caribou consumed was greater than the number of Moose consumed for all summers. The percent biomass consumed of Caribou was significantly greater ($P < 0.05$) than that of Moose only for the summer 1988.

Key Words: Gray Wolf, *Canis lupus*, diet, scat analysis, summer, Alaska.

A majority of the studies on summer diet of Gray Wolves, *Canis lupus*, in North America by scat analysis indicate that ungulates are the predominant prey consumed based on percent frequency of occurrence (Murie 1944; Cowan 1947; Mech 1966; Pimlott et al. 1969; Clark 1971; Kuyt 1972; Carbyn 1975; Van Ballenberghe et al. 1975; Voigt et al. 1976; Peterson 1977; Scott and Shackleton 1980; Peterson et al. 1984; Messier and Crete 1985; Ballard et al. 1987; Fuller 1989; Thurber and Peterson 1993). Beaver (*Castor canadensis*), lagomorphs, and microtine rodents comprise most of the remaining diet of Gray Wolves and may be seasonally or locally important, or sustaining during declines in ungulate populations.

An example of such an ungulate decline can be seen in areas where Caribou, *Rangifer tarandus*, migrate out of an area in early spring to their calving grounds for the summer. As a result, wolf packs that normally prey on Caribou may become temporarily separated from Caribou during summer and may have to shift their diet to other prey. Banfield (1954) suggested that small, non-ungulate prey may be critically important in the summer diet of wolves denning in areas where Caribou are migratory. Pimlott (1967) believed that wolves will prey upon low numbers of Caribou because alternate ungulate prey were not available. Subsequent studies have supported Pimlott's (1967) argument that Caribou or other ungulates are the primary source of food for wolves in summer and winter (Clark 1971; Kuyt 1972; James 1983; Ballard et al. 1987; Dale et al. 1993).

We collected scats as part of a larger study on the predation and demographics of wolves in northwestern Alaska (Ballard 1993; Ballard et al. 1997).

Ballard et al. (1997) reported that wolves preyed primarily on Caribou (51%) and Moose, *Alces alces* (42%), based on aerial observations of wolf kills. Ballard et al. (1997) reported that when Caribou migrated out of the area in early winter and their densities dropped, Wolves switched to preying on Moose. After spring it was not known if wolves continued to prey on Moose, or returned to preying on Caribou or other prey species.

The objectives of our study were to determine summer diet of Gray Wolves in northwestern Alaska based on the analysis of scats, to determine if wolves continued to use Moose as their primary prey after Caribou had migrated out of the area, and to determine to what degree Wolves used non-ungulate prey.

Study Area

The study area encompassed about 12 300 km² in northwestern Alaska and included the northern portions of Koyukuk National Wildlife Refuge, the eastern half of Kobuk Valley National Park, and the eastern two-thirds of Selawik National Wildlife Refuge. Topography varied from broad, flat plains along major rivers to steep mountainous terrain in the major mountain ranges such as the Purcell Mountains. Elevations ranged from sea level along major rivers to 1231 m for mountain peaks. Detailed study area descriptions are provided by Ballard et al. (1997).

Mammals found in the study area included shrews (*Sorex* spp.), Snowshoe Hare (*Lepus americanus*), Arctic Ground Squirrel (*Spermophilus parryi*), Beaver, microtine rodents (Brown Lemming [*Lemmus sibiricus*], Northern Red-backed Vole [*Clethrionomys* spp.]), and Arctic Skunk (*Mephitis mephitis*).

onomys rutilus], and voles [*Microtus* spp.], Muskrat (*Ondatra zibethicus*), Arctic Fox (*Alopex lagopus*), American Marten (*Martes americana*), Brown Bear (*Ursus arctos*) and Black Bear (*U. americanus*), Moose, Caribou, and Dall's Sheep (*Ovis dalli*) (Burt and Grossenheider 1976; Ballard 1993).

Birds found in the study area and considered potential prey of wolves included Greater White-fronted Goose (*Anser albifrons*), Canada Goose (*Branta canadensis*), Green-winged Teal (*Anas crecca*), Northern Pintail (*A. acuta*), American Wigeon (*A. americana*), Ptarmigan (*Lagopus* spp.), and Spruce Grouse (*Dendragapus canadensis*) [Anonymous, Draft checklist of birds, National Park Service, Kotzebue, Alaska, 1996, unpublished pamphlet].

Wolf pack territories were distributed across the study area (Ballard et al. 1997). Identification of individual den and rendezvous sites was facilitated through monitoring of radiocollared individuals within each pack. Distribution of individual wolf pack territories was provided by Ballard et al. (1997:figure 4).

Methods

During August and September 1988–1990, scats were collected from nine dens and one rendezvous site and represented the diet of the respective Gray Wolf packs from mid-May through July when these sites were occupied by wolves. We attempted to collect all scats deposited that year. A total of 1182 scats were collected. We made gross identifications of hair, teeth, bones, and feathers using keys (Adorjan and Kolenosky 1969; Glass 1973; Moore et al. 1974; Kennedy and Carbyn 1981; Gilbert 1990) and a reference collection at The University of Arizona. When necessary, we examined hair microscopically, compared it to a reference collection, and identified it to species by cuticular scale and medullary patterns (Adorjan and Kolenosky 1969; Moore et al. 1974). We considered frequency of occurrence as the number of scats in which a prey item occurred and percent frequency of occurrence as the number of occurrences of each prey item expressed as a percentage of the total number of prey items found (Lockie 1959).

To calculate biomass of prey consumed we estimated the relative volumetric proportion, or relative estimated bulk, of each prey item in each scat and then summed these to give the equivalent number of scats (n), representing the particular prey type for each pack sample. To estimate the weight of prey eaten per scat sample (y), we used Weaver's (1993) regression equation: $y = 0.439 + 0.008x$ where x is the mean adult weight of a given prey type (Floyd et al. 1978; Corbett 1989; Weaver 1993; Spaulding 1996).

We obtained mean prey weights for mammals from the literature (Skoog 1968; Burt and

Grossenheider 1976; Franzmann et al. 1978; Fuller 1989). To obtain a mean prey weight for birds we used published weights of each of the species (Dunning 1984) and used a weighted average for unidentified bird items (Spaulding 1996).

Prey species ≤ 2 kg were not corrected for digestibility. We assumed that each occurrence was an individual and it was unlikely that prey of that size would comprise a total scat (Ackerman et al. 1984). The percent frequency of occurrence, relative to the number of scats, for that prey item was multiplied by the mean weight of the prey item to estimate the biomass consumed. Prey species to which no correction factor was applied were Arctic Ground Squirrel, microtines, birds, Snowshoe Hare, and Muskrat (Spaulding 1996).

We made statistical comparisons among packs and years based on proportions of biomass consumed of each prey species. We used chi-square tests (1 df, $P = 0.05$) with Yates correction for continuity from 2×2 contingency tables (Zar 1996). We used the Fisher exact test when ≤ 5 expected observations were encountered in any cell of the 2×2 contingency table (SigmaStat, Jandel Science, San Rafael, California 1994). For comparisons of packs between years we used packs with ≥ 100 scats/year.

Results

Scats contained 1742 prey items and 15 different prey types. Because we were unable to discriminate consistently between calf and adult ungulate hair, we combined results for Moose and Caribou age classes. For all years Caribou comprised an average of 47% of all items and occurred in 69.3% of all scats. Moose comprised an average of 21.9% of all occurrences and microtines 10.6%. Medium-sized mammals, primarily Beaver plus Snowshoe Hare, Arctic Ground Squirrel, and Muskrat, comprised only 5.6% overall. Birds, primarily Ptarmigan, comprised an average of 13.6% of occurrences but were found in 20.4% of all scats.

Caribou was the predominant prey type comprising 46.9% of the total biomass. Moose comprised 43.2%, birds 6.7% and the remaining mammal prey items $< 4\%$ of the total biomass consumed for the three summers.

Ungulates comprised 90.1% of the total biomass consumed but only 3.4% of the number of individuals consumed. Birds were second in biomass (6.7%) and made up 50.4% of individuals eaten. Although birds and microtines ranked 1 and 2, respectively, in numbers of individuals eaten, they composed only 7.2% of the total biomass consumed.

Between-year-by-pack analyses based on proportions of biomass consumed of each prey type were done for the Ingruksukruk and Nuna Creek packs. When comparing biomass consumed in 1988 and

1990, the Ingruksukruk pack showed a significant increase in Moose, 14% in 1988 vs. 36% in 1990 ($\chi^2 = 15.3$, $P < 0.001$), and a decrease in bird consumption, 24% in 1988 vs. 7% in 1990, ($\chi^2 = 13.2$, $P < 0.001$). All other prey categories showed no significant differences. When comparing biomass consumed in 1989 and 1990, the Nuna Creek pack showed an increase in Moose, 41% in 1989 vs. 62% in 1990 ($\chi^2 = 14.9$, $P < 0.001$), and a decrease in Caribou, 50% in 1989 vs. 29% in 1990 ($\chi^2 = 18.0$, $P < 0.001$). There were no significant changes in biomass consumed for all other prey types.

We examined differences between packs in biomass consumed by comparing packs within the same year. In 1988 significantly fewer Moose, 0% vs. 14% ($\chi^2 = 17.5$, $P < 0.001$) and birds, 6% vs. 24% ($\chi^2 = 15.1$, $P < 0.001$), and significantly more Caribou, 92% vs. 56% ($\chi^2 = 46.5$, $P < 0.001$) were consumed by the Pick River pack than by the Ingruksukruk pack. In 1989, the Purcell Mountain pack consumed significantly less Caribou, 38% vs. 50% ($\chi^2 = 5.6$, $P < 0.05$) and significantly more Muskrat, 5% vs. 0.5% ($\chi^2 = 5.6$, $P < 0.05$) than the Nuna Creek pack. In 1990, the Nuna Creek pack consumed significantly more biomass of Moose, 62% vs. 36% ($\chi^2 = 22.4$, $P < 0.001$) and less of Caribou, 29% vs. 55% ($\chi^2 = 22.2$, $P < 0.001$) than did the Ingruksukruk pack. No other prey types showed significant differences among the aforementioned packs for the years analyzed.

Discussion

Pimlott (1967) suggested that wolves may commonly prey upon Caribou stragglers as defined by Murie (1944:54) in the absence of large numbers of Caribou. Kuyt (1972) documented that Caribou occurred in over 80% of scats from a portion of the study area where Caribou appeared to be nearly absent. James (1983) found percent frequency of occurrence of Caribou in scats was $> 74\%$, with small rodents making up the balance of the diet for a study pack contained within our study area. Even though Caribou moved out of the area during summer and were presumably in low densities, wolf packs still depended heavily on Caribou. Moose were not sufficiently abundant in the area for wolves to reduce their dependence on Caribou (Stephenson and James 1982; James 1983). When ≥ 2 species of large prey inhabit the same area, wolves will concentrate on the smallest or easiest to catch (Mech 1970). Peterson (1955: 175) found that even though Moose were much more abundant than White-tailed Deer (*Odocoileus virginianus*) on St. Ignace Island, Ontario, deer comprised the largest portion of prey occurrences in scats. Dale et al. (1993) concluded that wolves continued to prey on Caribou even when Moose were twice as abundant as Caribou. No evidence of prey switching was found due to changes in ungulate abundance.

Ballard et al. (1997) reported that during 1988–1990 wolves selected Caribou when they were available. Based on aerial observations and monitoring of radiocollared Caribou, Ballard et al. (1987) indicated that Caribou largely left the study area after January, wolves then switched to preying upon Moose. Ballard et al. (1997) used the relative occurrence of radiocollared Caribou within the study area as an index of Caribou abundance. We found that the percent frequency of occurrence of Caribou in scats was significantly greater than for Moose for May–July, 1988–1990. Limited aerial observations by Ballard et al. (1997) during May through September, 1987–1992, suggested that Moose and Caribou were consumed in equal proportion. Wolves switched to preying on Moose during January through April during years when Caribou numbers were greatly reduced and Moose were more vulnerable due to snow conditions (Ballard et al. 1997), but by June of each year Caribou were once again the predominant prey item. The percent frequency of occurrence of Caribou in the wolves' diet increased from spring to summer and Caribou were the predominant prey item found in scats during summer. The amount of Moose in the diet of the wolves in the study area was not enough to reduce significantly the packs' dependence on Caribou despite the low densities of Caribou during all three summers. Moose were also estimated to be at low densities ($166/1000 \text{ km}^2$) in the study area (Ballard et al. 1997). This low density of Moose and the assumption that Moose were more formidable and less vulnerable than Caribou to wolf predation (Murie 1944; Peterson 1955; Mech 1970; Dale et al. 1993) may partially explain why the wolves in the study area selected the relatively few Caribou present during summer. Another explanation which can not be discounted is that wolves scavenged Caribou carcasses left over from hunter kills.

The differences in the summer diets of the different packs may reflect differences in the availability and vulnerability of prey species within the home ranges of individual packs. For example, in 1988 the significantly higher biomass of birds consumed by the Ingruksukruk pack compared to the Pick River pack may be the result of a higher availability of birds and their nests and young to predation. Overall, the higher incidence of birds in the summer diet may reflect the greater availability and vulnerability to predation by wolves of ground nesting birds on their breeding grounds. The differences in Caribou, Moose, and Muskrat biomass consumed between the Ingruksukruk, Pick River, Purcell Mountain, and Nuna Creek packs may correspond with differences in availability of these prey within the pack's respective home ranges.

Although ungulates were the predominant prey during summer, microtines and birds made up 10.6 and 13.8% of scat contents, respectively. Kuyt

(1972) found similar percent frequency of occurrence of birds and microtines in the Northwest Territories, Canada. Although percent biomass consumed was only 7.2% in our study, a better estimate of the numerical importance of smaller prey in the diet was provided by calculating the number of individuals eaten. In all years ungulates were only 3.4% of the animals eaten and small animals became more abundant in the diet than was suggested by biomass alone. For every Caribou consumed, 13 microtines or 17 birds were eaten, rather than 1 for every 3 or 4 Caribou as was concluded from percent frequency of occurrence data.

Small prey such as birds and microtines may be important prey items between periods of ungulate kills, especially in summer when ungulate prey were at lower densities than in winter. There is also a higher nutritional demand by the pack during summer when raising pups (Mech 1970). Other studies have also shown a greater use of alternative food resources, especially during summer, by wolves in areas of low ungulate densities (Voigt et al. 1976; Peterson 1977; Messier and Crete 1985; Ballard et al. 1987). The presence and importance of these alternative, small, non-ungulate prey can only be determined by a thorough and complete scat analysis of the representative wolf packs.

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Habitat de reproduction et succès de nidification d'une population introduite de Tétrás du Canada, *Falci pennis canadensis*, dans l'île d'Anticosti, Québec

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Le Tétrás du Canada (*Falci pennis canadensis*) a été introduit dans l'île d'Anticosti en 1985 et 1986. Cette introduction a fourni l'opportunité d'étudier la structure de l'habitat de reproduction là où la faible densité des individus n'affectait pas le choix des sites. Pour caractériser les habitats fréquentés, huit femelles et six mâles ont été munis d'un émetteur. Ces oiseaux ont été localisés à tous les 1,5 jours en moyenne, du 18 mai au 9 juillet 1986 pour un total de 91 localisations pour les femelles et 103 pour les mâles. Globalement, les habitats utilisés par l'ensemble des Tétrás du Canada se distinguent de l'habitat disponible ($n = 55$) par une strate arbustive plus développée, particulièrement durant les périodes de nidification et d'élevage. Les mâles fréquentent un plus grand éventail d'habitats que les femelles. La fréquentation d'habitats plus ouverts durant la période de pré-nidification pourrait faciliter le comportement de parade nuptiale. Après l'accouplement, ils utilisent des habitats possédant une végétation arborescente et arbustive dense qui compenserait la capacité de vol réduite (mue) par un meilleur couvert de fuite face aux prédateurs. Les femelles nidifient dans des habitats comparables à ceux occupés par les mâles durant la même période; elles y retrouveraient, tout comme les mâles, un meilleur couvert pour contrer la prédation. L'habitat fréquenté par les femelles lors de la première semaine d'élevage se compare à celui utilisé durant la période de nidification. Par contre, l'habitat utilisé lors de la deuxième et de la troisième semaine d'élevage se distingue par des strates arborescente et arbustive d'une densité plus faible, indiquant la fréquentation de peuplements plus matures. Le succès de nidification pour la première année de reproduction fut de 62,5 p. cent. Les résultats de cette étude sont dans l'ensemble conformes à ceux obtenus antérieurement dans d'autres régions et laissent croire au succès de cette introduction.

Mots clés: Tétrás du Canada, *Falci pennis canadensis*, introduction, reproduction, habitat, Québec.

Spruce Grouse (*Falci pennis canadensis*) were introduced on Anticosti Island in 1985 and 1986. This introduction provided an opportunity to study habitat utilization where low population density did not affect habitat selection. In order to study habitat utilization, eight females and six males were equipped with radio-transmitters. These birds were located on average once every 1.5 days between 18 May and 9 July 1986 for a total of 91 locations for the females and 103 for the males. Overall, sites used by Spruce Grouse were characterized by a dense shrub layer, particularly during nesting and brooding periods when compared with control sites. Males used a broader range of habitats when compared with females. The utilization of an open habitat during the breeding period compared to the other periods and may be related to the greater efficiency of the breeding display in such habitat. After the breeding period, males utilized sites having a denser tree and shrub layers, possibly to reduce predation risk as their flying capacity is reduced during molting. Females nest in sites having similar characteristics to those used by males during this period, seeking sites that can potentially reduce predation risk. Sites utilized during the first week of the brooding period were comparable to those used during the nesting period. However, during the second part of the brooding period, females moved to older stands characterized by lower tree and shrub densities. In the first year following introduction, nesting success was 62.5 percent. Results obtained in this study supported previous findings obtained in other regions and suggested that this introduction will be a success.

Key Words: Spruce Grouse, *Falci pennis canadensis*, introduction, reproduction, habitat, Québec.

Plusieurs études ont défini les habitats utilisés par le Tétrás du Canada (*Falci pennis canadensis*), notamment en Alaska (Ellison 1966), au Michigan (Robinson 1969), au Minnesota (Anderson 1973; Haas 1974; Pietz et Tester 1982), en Alberta (McCourt 1969; McLachlin 1970; Keppie et Herzog 1978), dans l'état de Washington (Ratti et al. 1984), au Montana (Paterni 1979; Herman 1980), dans le Maine (Hedberg 1980; Allan 1985), en Ontario (Szuba et Bendell 1983 in Boag et Schroeder 1992)

et au Québec (Turcotte et al. 1993). Il en ressort que le tétras est étroitement associé aux forêts dominées par les conifères (Boag et Schroeder 1992). De plus, à l'intérieur même des forêts de résineux, il semble choisir des portions spécifiques en fonction des saisons, des sexes et des groupes d'âge (Boag et Schroeder 1992). Cependant, en période de reproduction, peu d'études (Hedberg 1980; Turcotte et al. 1993) ont considéré à la fois les caractéristiques des habitats fréquentés par les mâles et les femelles.

Durant la nidification, il appert que la composition de la végétation et le camouflage du nid peuvent influencer le succès de reproduction (Keppie et Herzog 1978; Redmond et al. 1982).

Au cours des étés 1985 et 1986, un total de 343 Tétràs du Canada de la sous-espèce *F. c. canadensis* ont été introduits dans l'île d'Anticosti. L'isolement géographique de l'île par rapport au continent empêchait la colonisation naturelle par cette espèce. Les oiseaux ont été capturés sur le continent, à proximité de l'île, soit sur la Côte Nord du fleuve Saint-Laurent (Ferron et Lemay 1987). Les résultats du suivi de la population permettent de croire que l'implantation a bien réussi (Ferron et Lemay 1987; Laprise 1988*). Cette introduction offrait l'opportunité de réaliser une étude sur la composition structurale de l'habitat du tétras. L'intérêt du présent travail découle entre autre du fait que l'habitat n'était pas occupé par cette espèce. Les sites choisis ne sont donc pas fonction de la densité de la population (Van Horne 1983). Par ailleurs, notre intérêt a principalement porté sur les habitats de reproduction et le succès de nidification puisque, d'une part, le fait de savoir que les tétras nouvellement introduits pouvaient se reproduire dans leur nouvel habitat constituait un signe indicateur de réussite de l'introduction et que, d'autre part, l'étude de la reproduction se justifie pleinement compte tenu des rares analyses de sélection d'habitat durant cette période du cycle vital de cette espèce, particulièrement dans l'est du Canada.

L'objectif de cette étude était de déterminer les caractéristiques structurales et la composition végétale de l'habitat fréquenté par les mâles et les femelles Tétràs du Canada lors des périodes de pré-nidification, de nidification et d'élevage dans un nouveau milieu. De plus, nous traitons de certains éléments de la reproduction se rapportant plus spécifiquement à la nidification.

Aire d'étude

La zone d'étude se situe dans l'île d'Anticosti dans le golfe du Saint-Laurent au Québec, sur le secteur de la rivière La Loutre (49°42' N, 63°38' O). Le domaine écologique est la sapinière à Épinette blanche (Grandtner 1966). La forêt est principalement composée de résineux dont le Sapin baumier (*Abies balsamea*), l'Épinette blanche (*Picea glauca*), l'Épinette noire (*Picea mariana*), le Mélèze laricin (*Larix laricina*), et en moindre abondance le Pin blanc (*Pinus strobus*). On dénote aussi la présence de petits îlots de feuillus généralement composés de Peuplier baumier (*Populus balsamifera*), de Peuplier faux-tremble (*Populus tremuloides*) ou de Bouleau à

papier (*Betula papyrifera*). Soulignons aussi que la végétation de l'île est fortement influencée par la présence d'une importante population de Cerfs de Virginie (*Odocoileus virginianus*) qui affecte considérablement la régénération des feuillus et de certains résineux, particulièrement le Sapin baumier (Huot 1982).

D'une superficie de 7943 km², l'île d'Anticosti jouit d'un climat maritime avec une température hivernale plutôt douce et des conditions estivales plutôt fraîches avec une température moyenne de 14°C. Les prédateurs terrestres du tétras sont pratiquement absents exception faite du Renard roux (*Vulpes vulpes*) qui est abondant. Les principaux prédateurs aviaires comme le Grand-duc d'Amérique (*Bubo virginianus*) et l'Autour des palombes (*Accipiter gentilis*) sont aussi présents. Soulignons aussi la présence de la Gélinothe huppée (*Bonasa umbellus*) introduite au début du 20^{ème} siècle. Cette espèce ne présente cependant que de faibles densités en raison d'une forêt en majorité composée de résineux constituant un habitat de faible qualité pour cette espèce.

Matériel et méthodes

Télémétrie

Huit femelles et six mâles tétras ont été capturés au sol ou dans les arbres à l'aide de perches télescopiques de fibre de verre d'une longueur maximale de 5 m et munies à l'extrémité d'un collet permettant de capturer l'oiseau par le cou (Zwickel et Bendell 1967). Un émetteur pesant 14 g a été fixé au dos de chaque oiseau au moyen d'un harnais de type "sac à dos" constitué d'un fil de métal souple de sept brins, recouvert d'une gaine de caoutchouc. Les tétras ont été localisés à tous les 1,5 jour en moyenne, du 18 mai au 9 juillet 1986, à l'aide de récepteurs portatifs munis d'antenne de type Yagi. Une approche discrète de la part des observateurs évitait d'effrayer et de faire bouger les tétras. Une attention toute particulière fut portée aux femelles en nidification. Lorsque la végétation le permettait, la localisation des femelles sur le nid se faisait à distance pour ne pas fournir d'indices visuels et olfactifs aux prédateurs. La localisation par triangulation a été aussi utilisée à quelques reprises en vue de minimiser les visites au nid.

Description et utilisation de l'habitat

Les habitats utilisés par les femelles et les mâles ont été étudiés durant trois périodes: (1) pré-nidification (18 au 28 mai); (2) nidification, correspondant à l'incubation des œufs, (29 mai au 23 juin); et (3) élevage, c'est-à-dire au cours des trois premières semaines d'élevage des jeunes (24 juin au 9 juillet). Au total, 91 localisations ont été enregistrées pour les femelles et 103 pour les mâles.

Des sites témoins (n = 55) ont été sélectionnés afin de caractériser l'habitat disponible et de vérifier

*voir Document Cité

l'existence d'une préférence pour des sites possédant des caractéristiques particulières. Comme la composition végétale de la forêt présentait une certaine homogénéité, la sélection des ces sites fut réalisée de façon aléatoire sur une série de transects couvrant l'aire utilisée par l'ensemble des oiseaux suivis par télémétrie.

Les variables choisies pour caractériser à la végétation (Tableau 1) ont été adaptés des travaux de Hedberg (1980) et Ratti et al. (1984). Les données ont été recueillies à l'intérieur d'une parcelle de forme octogonale de 76 m² et subdivisée en 8 parties égales pour fins d'échantillonnage. Le centre de la parcelle correspond à la localisation d'un tétras. Dans le cas d'un site témoin, le point central correspond au point choisi aléatoirement. Les données

reliées à la strate arborescente (DHP ≥ 7cm) ont été mesurées sur toute la superficie de la parcelle tandis que les strates arbustive (DHP < 7 cm et hauteur > 50 cm) et herbacée (hauteur < 50 cm), ont été échantillonnées respectivement sur 38 m² et 1 m². Le diamètre de chaque tige a été déterminé à l'aide d'un compas forestier. La surface terrière a été déterminée à partir de la densité et du diamètre moyen des tiges (Avery 1967). La hauteur moyenne des arbres dans la parcelle a été estimée à l'aide d'un clinomètre. La hauteur moyenne de la base de la voûte forestière a été obtenue à partir de mesures effectués au moyen d'une perche télescopique graduée sur l'ensemble des arbres de la parcelle. La couverture arborescente (végétation supérieure à 1,5 m de hauteur) a été estimée à l'aide d'un posemètre (Devos et Mosby,

TABLEAU 1: Caractéristiques des sites témoins et des sites fréquentés par les femelles Tétràs du Canada au cours des périodes de pré-nidification, nidification et d'élevage. Les données correspondent à la moyenne pour chaque catégorie de site observé. L'écart-type est entre parenthèses. Les lettres sont utilisées pour représenter les différences significatives entre les groupes.

Variable	P	Témoin (n = 55)	Pré-nidification (n = 39)	Nidification (n = 8)	Élevage (n = 44)
Densité arborescente (tiges/ha)					
Épinette noire	0,1126	536 (593,2)	631 (629,0)	1234 (1028,7)	703 (669,1)
Épinette blanche	0,0068	26 (108,6)	88 (148,9)	132 (211,0)	51 (121,1)
Sapin baumier	0,0630	813 (691,7)	756 (484,6)	921 (706,8)	532 (518,6)
totale	0,1005	1395 (884,0)	1484 (686,3)	2286 (1080,3)	1340 (730,8)
Surface terrière (m ² /ha)					
Épinette noire	0,1341	6,8 (7,54)	9,3 (9,58)	12,7 (11,14)	7,3 (7,13)
Épinette blanche	0,0048	0,8 (3,17)	5,0 (8,20)	4,8 (7,54)	2,9 (6,27)
Sapin baumier	0,5605	12,4 (11,81)	11,1 (6,94)	11,0 (10,41)	10,3 (10,92)
totale	0,0720	20,7 (12,5)	25,5 (11,55)	28,4 (13,23)	20,3 (11,85)
Diamètre moyen des arbres (cm)	0,3660	12,4 (6,22)	13,9 (3,46)	12,0 (2,27)	13,2 (3,92)
Hauteur du couvert (m)	0,6277	8,3 (3,97)	9,2 (2,28)	7,8 (1,74)	9,1 (3,43)
Couverture arborescente (%)	0,0384	10,4 ^{ab} (6,56)	12,7 ^a (6,23)	10,4 ^{ab} (6,30)	9,0 ^b (5,63)
Hauteur de la base de la voûte forestière (m)	0,4783	2,9 (2,08)	2,6 (1,20)	2,9 (1,53)	2,5 (1,40)
Densité arbustive (tiges/ha)					
Épinette noire	0,0118	4660 ^a (6258,2)	5722 ^{ab} (4626,6)	7862 ^{ab} (4653,5)	7159 ^b (5897,1)
Sapin baumier	0,3306	1201 (1774,6)	1363 (1222,3)	987 (875,6)	1065 (1107,7)
totale	0,0175	6196 ^a (6547,4)	7227 ^{ab} (4926,5)	8849 ^{ab} (4289,5)	8923 ^b (5485,2)
Recouvrement végétal au sol (%)	0,0004	19 ^a (20,6)	33 ^b (26,3)	38 ^b (20,3)	40 ^b (24,5)
Densité herbacée (tiges/ha)	0,0035	42 ^a (61,2)	57 ^{ab} (80,1)	41 ^{ab} (35,1)	73 ^b (57,3)

1969). Le recouvrement végétal au sol, c'est-à-dire la végétation se situant à moins de 1,5 m du sol, a été estimé visuellement à partir d'une analyse a posteriori d'une photographie prise au dessus de la parcelle à l'aide d'un appareil photographique muni d'une lentille de 28 mm.

La situation spatiale (i.e., au sol ou dans les arbres) des tétras a été notée lors des localisations afin de préciser l'utilisation de l'habitat. Lorsqu'un animal était sur un arbre, nous avons aussi pris note de l'essence utilisée.

Succès de reproduction

Lors de la période de nidification, les femelles ont été localisées pratiquement à tous les jours de manière à déterminer la durée de l'incubation, le nombre d'oeufs pondus, le nombre d'oeufs éclos et le succès de nidification.

Traitement des données

Nous avons considéré que les positionnements étaient indépendants les uns des autres compte tenu qu'un animal n'était jamais localisé deux fois de suite sur un même site. De plus, un oiseau n'était jamais localisé deux fois au cours d'une même journée. Par contre, pour les femelles durant la période de nidification, nous n'avons retenu qu'un site par femelle, soit l'emplacement du nid, pour éviter toute forme de biais. Ainsi, pour les femelles durant la période de nidification, l'habitat décrit représente les caractéristiques de la végétation entourant l'emplacement du nid. Nos observations suggèrent d'ailleurs que les femelles s'éloignaient peu du nid.

Étant donné que, pour la plupart des variables, il était impossible de respecter les conditions d'applications de l'analyse de variance (Wilkinson et al. 1996), des analyses non-paramétriques ont été effectuées. Nous avons comparé les caractéristiques des sites témoins et des sites fréquentés aussi bien par les femelles que par les mâles, au cours des périodes de pré-nidification, de nidification et d'élevage à l'aide du test de Kruskal-Wallis suivi, lorsque nécessaire, d'un test de comparaisons multiples S.N.K à partir des données ordonnées en rang (Scherrer 1984). Nous avons également analysé les caractéristiques de l'habitat fréquenté par les femelles afin de vérifier si elles changeaient d'habitat au cours de la période d'élevage en comparant les caractéristiques des sites utilisés durant la première semaine de cette période à celles correspondant aux sites fréquentés au cours des deux semaines subséquentes à l'aide du test de Mann-U-Whitney. Nous avons vérifié si la situation spatiale (i.e., au sol ou dans les arbres) variait pour les mâles et les femelles par des tests de comparaison de fréquences (test de G). Pour les localisations dans les arbres, nous avons vérifié si les oiseaux sélectionnaient une essence plutôt qu'une autre en

comparant leur utilisation avec la disponibilité des principales essences du milieu (test de G). Le seuil de signification utilisée est 0.05.

Résultats

Utilisation de l'habitat durant la reproduction

Femelles

Dans l'ensemble les caractéristiques des sites fréquentés par les femelles diffèrent peu des sites témoins (Tableau 1). Aucune différence significative dans la strate arborescente n'existe entre les sites utilisés et les sites témoins. Par contre, au niveau de la strate arbustive, la densité des arbustes est significativement plus élevée pour les sites utilisés par les tétras, particulièrement durant les périodes de nidification. De même, le recouvrement végétal au sol est plus élevé dans les sites fréquentés. La densité herbacée, quant à elle, est plus élevée lors de la période d'élevage par rapport aux sites témoins.

Les caractéristiques des sites fréquentés par les femelles diffèrent peu entre les périodes de pré-nidification, de nidification et d'élevage (Tableau 1). En effet, à l'exception d'une couverture arborescente qui est significativement plus importante lors de la période de pré-nidification par rapport à la période d'élevage, aucune propriété ne diffère entre les sites utilisés lors des trois périodes de reproduction. Bien que les différences ne soient pas significatives, les sites fréquentés par les femelles durant la période de nidification se distinguent par une densité arborescente et une surface terrière supérieures, ainsi que par une densité herbacée inférieure par rapport aux observations réalisées lors des périodes de pré-nidification et d'élevage.

Les caractéristiques des sites diffèrent à de nombreux égards avec l'avancement de la période d'élevage (Tableau 2). Au niveau de la strate arborescente, les sites fréquentés lors de la seconde partie de la période d'élevage se distinguent notamment par des arbres possédant un diamètre plus élevé et la hauteur de la base de la voûte offert par ceux-ci est plus élevé par rapport au sol. La densité arborescente et la surface terrière de l'Épinette noire diminuent considérablement entre les sites fréquentés la première semaine et ceux utilisés au cours des deux semaines subséquentes alors que celles de l'Épinette blanche augmentent. Mentionnons aussi, la présence d'une strate arbustive moins développée dans les sites choisis lors de la seconde période en raison de la diminution du nombre de jeunes tiges d'Épinette noire. De plus, bien que la différence ne soit pas statistiquement significative, le recouvrement végétal au sol diminue alors que la densité herbacée augmente dans l'habitat fréquenté durant la seconde partie de la période d'élevage. Finalement, une série de tests de Mann-U-Whitney indique que les caractéristiques des sites fréquentés durant la première semaine de la période d'élevage ne diffèrent pas sig-

TABLEAU 2: Caractéristiques des sites fréquentés par les femelles Tétràs du Canada au cours des trois premières semaines de la période d'élevage. Les données correspondent à la moyenne pour chaque catégorie de site observé. L'écart-type est entre parenthèses.

Variable	P	sem.1 (n = 20)	sem.2 et 3 (n = 24)
Densité arborescente (tiges/ha)			
Épinette noire	0,0003	1092 (681,8)	378 (459,6)
Épinette blanche	0,0100	7 (29,4)	88 (153,6)
Sapin baumier	0,1505	461 (592,3)	592 (452,5)
autres	0,5818	7 (29,4)	124 (495,4)
totale	0,0778	1566 (890,3)	1151 (512,2)
Surface terrière (m ² /ha)			
Épinette noire	0,0004	11,1 (7,32)	4,2 (5,30)
Épinette blanche	0,0117	0,6 (2,68)	4,7 (7,69)
Sapin baumier	0,0604	7,7 (11,49)	12,4 (10,17)
totale	0,2942	18,7 (13,13)	21,6 (10,78)
Diamètre moyen des arbres (cm)	0,0041	11,0 (3,97)	14,5 (4,06)
Hauteur du couvert (m)	0,0028	7,4 (3,26)	10,4 (2,98)
Couverture arborescente (%)	0,3829	8,2 (5,66)	9,7 (5,63)
Hauteur de la base de la voûte forestière (m)	0,4717	2,4 (1,65)	2,4 (1,27)
Densité arbustive (tiges/ha)			
Épinette noire	0,0002	10882 (5941,3)	4057 (3710,2)
Épinette blanche	0,0178	0 (0,0)	921 (2160,3)
Sapin baumier	0,1069	842 (1188,0)	1250 (1024,4)
totale	0,0008	11974 (5819,9)	6382 (3665,6)
Recouvrement végétal au sol (%)	0,0676	45 (25,1)	33 (24,1)
Densité herbacée (tiges/ha)	0,1607	66 (69,2)	78 (45,8)

nifiquement des sites utilisés lors de la période de nidification.

Mâles

Chez les mâles, les caractéristiques des sites fréquentés durant les périodes de nidification et d'élevage diffèrent à plusieurs égards de celles des sites témoins (Tableau 3). Quoique la densité de l'ensemble des tiges ne diffère pas au niveau de la strate arborescente, l'Épinette noire est plus abondante et possède une surface terrière plus importante dans les sites fréquentés que dans les sites témoins. La hauteur de la base de la voûte forestière est généralement plus basse dans les sites fréquentés. La strate

arbustive est plus développée dans les sites fréquentés durant la période de nidification et d'élevage alors que durant la pré-nidification, elle diffère peu de ce que l'on observe dans les sites témoins. L'Épinette noire est nettement plus abondante au niveau arbustif sur les sites fréquentés durant les deux dernières périodes de la reproduction. La densité herbacée est également plus élevée dans les sites utilisés durant la nidification et lors de la période d'élevage.

Sol vs arbre

Les femelles se retrouvent dans les arbres 55 p. cent (n = 33) du temps au cours de la période de pré-

TABLEAU 3: Caractéristiques des sites témoins et des sites fréquentés par les mâles Tétràs du Canada au cours des périodes de pré-nidification, nidification et d'élevage. Les données correspondent à la moyenne pour chaque catégorie de site observé. L'écart-type est entre parenthèses. Les lettres sont utilisées pour représenter les différences significatives entre les groupes.

Variable	P	Témoïn (n = 55)	Pré-nidification (n = 27)	Nidification (n = 49)	Élevage (n = 27)
Densité arborescente (tiges/ha)					
Épinette noire	0,0001	536 ^a (593,2)	819 ^b (562,2)	956 ^b (607,6)	1033 ^b (584,7)
Épinette blanche	0,0062	26 ^a (108,6)	58,5 ^{ab} (117,32)	67,1 ^b (126,33)	19,5 ^{ab} (60,00)
Sapin baumier	0,0405	818 ^{ab} (691,7)	940,8 ^a (533,5)	776,3 ^{ab} (488,8)	526,3 ^b (338,4)
totale	0,0560	1395 (884,0)	1847 (549,2)	1807 (763,8)	1603 (687,6)
Surface terrière (m ² /ha)					
Épinette noire	0,0018	6,8 ^a (7,54)	9,3 ^{ab} (5,83)	10,9 ^b (6,28)	10,6 ^b (6,23)
Épinette blanche	0,0101	0,8 (3,17)	2,1 (4,35)	3,4 (6,29)	1,8 (5,30)
Sapin baumier	0,0013	12,4 ^{ab} (11,81)	17,1 ^a (11,53)	10,3 ^{ab} (6,61)	6,9 ^b (5,17)
totale	0,0357	20,7 (12,54)	27,2 (10,67)	24,6 (10,99)	20,4 (9,01)
Diamètre moyen des arbres (cm)	0,6695	12,4 (6,22)	13,1 (2,60)	12,5 (2,35)	12,2 (2,05)
Hauteur du couvert (m)	0,1801	8,3 (3,97)	9,4 (2,59)	8,1 (1,76)	8,5 (1,92)
Couverture arborescente (%)	0,0572	10,4 (6,56)	16,1 (9,15)	12,3 (6,02)	10,6 (4,56)
Hauteur de la base de la voûte forestière (m)	0,0051	2,9 ^{ab} (2,08)	2,0 ^a (1,15)	2,1 ^{ab} (0,68)	1,8 ^b (0,60)
Densité arbustive (tiges/ha)					
Épinette noire	< 0,0001	4660 ^a (6258,2)	5029 ^a (4605,9)	7474 ^b (4232,0)	8118 ^b (4047,8)
Sapin baumier	0,0050	1201 ^a (1774,6)	1647 ^{ab} (1608,3)	2170 ^b (2753,2)	1598 ^b (1047,4)
totale	0,0001	6196 ^a (6547,4)	6706 ^a (5066,9)	9479 ^b (4884,2)	9737 ^b (4307,8)
Recouvrement végétal au sol (%)	< 0,0001	19 ^a (20,6)	26 ^{ab} (18,7)	39 ^b (20,8)	45 ^b (22,0)
Densité herbacée (tiges/ha)	0,0002	42 ^a (61,15)	24 ^a (52,3)	56 ^b (46,6)	54 ^b (60,6)

nidification, alors qu'elles fréquentent peu les arbres durant les deux périodes subséquentes (2%; n = 52, p < 0,05). Les mâles, par contre, se retrouvent davantage au sol pour toutes les périodes. Ces derniers se tiennent toutefois encore plus au sol (88,9%; n = 27) durant la période d'élevage par rapport aux périodes de pré-nidification (68,4%; n = 33) et d'élevage (67,4%; n = 49) (p < 0,05).

Les tétras mâles et femelles ont été localisés dans les trois espèces dominantes de conifères. L'Épinette blanche est toutefois l'essence dans laquelle les oiseaux ont été le plus souvent observés avec 77 p. cent des localisations, alors qu'ils sont observés dans l'Épinette noire et le Sapin baumier dans 18 et 5 p. cent du temps respectivement; il n'y pas de dif-

férence significative entre les sexes (p < 0,05). Les tétras utilisent de préférence l'Épinette blanche par rapport au Sapin baumier et à l'Épinette noire puisque cette dernière ne représente que 3,5 p. cent des tiges arborescentes disponibles dans l'aire d'étude (p < 0,001).

Succès de nidification

Les huit femelles que nous avons suivies ont couvé des oeufs. Le nombre moyen d'oeufs pondus était de $5,9 \pm 0,6$. Le succès de nidification se situe à 62,5 p. cent. Dans un cas, la femelle et les oeufs ont été détruits par un Renard roux alors que dans deux autres cas, seules les oeufs ont été détruits mais les prédateurs n'ont pas été identifiés. Pour ce qui est

des couvées menées à terme, l'incubation a duré en moyenne $23,8 \pm 0,4$ jours et le nombre moyen d'oeufs éclos par nid a été de $4,4 \pm 0,9$.

Discussion

Habitat de reproduction

La caractérisation de l'habitat de reproduction du Tétrás du Canada dans l'île d'Anticosti permet de constater que, dans l'ensemble, les mâles fréquentent un plus grand éventail d'habitats que les femelles. En effet, les caractéristiques des sites utilisés par les mâles variaient d'avantage entre les périodes de pré-nidification, de nidification et d'élevage par rapport aux femelles. Des observations comparables ont été rapportées au Minnesota (Anderson 1973; Haas 1974) et en Alberta (McCourt 1969; McLachlin 1970).

Durant la pré-nidification, les individus des deux sexes utilisent des sites dont la strate arbustive est moins importante quant à la densité et au recouvrement par rapport aux autres périodes. Le comportement des mâles au cours de la parade pourrait expliquer ce résultat. En raison de leur composantes visuelles et auditives, les parades seraient exécutées dans des milieux plus ouverts facilitant la localisation du mâle par les femelles ou les autres mâles des environs (Stoneberg 1967; McLachlin 1970). Durant la période d'accouplement, on observe des différences moins marquées entre l'habitat des mâles et celui des femelles que durant la saison estivale (McLachlin 1970; Turcotte et al. 1993).

Durant et après la nidification, les mâles utilisent des habitats caractérisés par une strate arbustive plus développée par rapport aux sites témoins. La végétation dense qu'ils y retrouvent pourrait favoriser un camouflage accru face aux prédateurs (McLachlin 1970; Hedberg 1980; Allan 1985) puisqu'à cette période, les mâles subissent une mue partielle. En Alberta, la mue des tétras mâles débute à la mi-juin pour se terminer au mois d'octobre; ils ont alors une capacité de vol réduite, notamment de la mi-juillet à la mi-août, lorsque les reproductrices sont absentes (McLachlin 1970).

Chez les femelles, il a été suggéré que le succès de la nidification serait directement proportionnel à la qualité du camouflage du nid (Keppie et Herzog 1978; Redmond et al. 1982). Dans la présente étude, les femelles ont placé leur nid dans un habitat plus dense tant au niveau arbustif qu'arborescent, en comparaison de ce que l'on retrouve en général sur l'aire d'étude. Il est aussi intéressant de constater que lorsque les femelles ou les mâles recherchent un couvert dense pour leurs besoins, ils utilisent les secteurs forestiers où l'ÉpINETTE noire est plus abondante. Il faut rappeler que sur l'île d'Anticosti, le Cerf de Virginie affecte la végétation forestière en réduisant considérablement la régénération ligneuse. Or nous avons constaté que cet effet est moins

important pour l'ÉpINETTE noire parce que le cerf consomme très peu cette essence (Huot 1982), d'où la recherche d'un tel couvert par les tétras.

Les données des trois premières semaines d'élevage permettent de constater que durant la première semaine, les femelles et leurs jeunes occupent un habitat comparable à ceux fréquentés durant la nidification. L'occupation de cet habitat pourrait être liée au besoin de protection des jeunes qui peuvent se dissimuler dans la végétation arbustive dense et à leur incapacité à réaliser de grands déplacements restant plus ou moins à proximité du site de nidification au cours des premiers jours suivant l'éclosion. La capacité d'un jeune à se dissimuler dans un habitat est particulièrement importante en début d'élevage puisque leur capacité de fuite est limitée. En fait, les jeunes tétras ne réalisent de courts vols qu'à l'âge de 6 à 8 jours (Boag et Schroeder 1992). Haas (1974) rapporte que les femelles avec couvée exécutent des déplacements de plus grande envergure avec le temps et qu'elles fréquentent alors une plus grande gamme de couverts forestiers. Nos résultats sont en accord avec cette observation puisque les caractéristiques des habitats fréquentés changent avec le temps. Même si nous n'observons aucune différence significative dans la densité des arbres entre les deux périodes, la composition relative en espèces varie. Ainsi, la densité de l'ÉpINETTE noire est plus faible dans les sites utilisés lors de la seconde partie de la période d'élevage. De plus, le diamètre et la hauteur des arbres indiquent que la forêt serait davantage mature. Mentionnons aussi que durant les deuxième et troisième semaine de la période d'élevage, ce qui favoriserait une meilleure disponibilité de nourriture végétale et surtout animale (arthropodes) pour les jeunes. Pendergast (1969) rapporte en effet que les juvéniles possèdent au cours des premières semaines de leur vie, un régime alimentaire presque exclusivement animal. Même si on observe des différences dans la structure des habitats d'élevage décrits entre les études de McCourt (1969), Haas (1974) et la nôtre, il semble y avoir dans les trois cas une sélection en faveur des milieux offrant une meilleure disponibilité de nourriture. Comme dans les études de Hedberg (1980) et d'Allan (1985), nous notons que les femelles utilisent des habitats plus ouverts au niveau arborescent et plus denses en végétation arbustive par rapport aux tétras mâles durant la seconde partie de la période d'élevage.

La distribution spatiale des tétras mâles et des tétras femelles au cours de la reproduction correspond, de façon générale, aux résultats obtenus par Allan (1985). Les mâles sont localisés dans les arbres dans une proportion constante avant et pendant la nidification alors qu'ils sont plus souvent au sol par la suite. Pour les femelles, l'utilisation des arbres est plus importante avant la nidification. Bien que nous ayons observé les femelles seulement sur

leur nid pendant cette période, nous sommes conscients qu'elles doivent délaissier leur couvée pour de courtes périodes pour s'alimenter puisque la recherche de nourriture se ferait surtout dans les arbres, durant de brèves périodes au lever et au coucher du soleil (McCourt et al. 1973).

L'ÉpINETTE blanche constitue l'essence la plus recherchée par le tétras pour se percher. De la même façon dans l'état du Maine, l'ÉpINETTE rouge, qui est la seule représentante du genre *Picea* dans cette région, est plus fréquemment utilisée comme perchoir que toutes les autres espèces (Allan 1985). Ellison (1976) mentionne qu'en Alaska le tétras préfère les aiguilles d'ÉpINETTE blanche à celles de l'ÉpINETTE noire parce qu'elles sont plus facile à récolter et plus facile à digérer. McCourt et al. (1973) et Herzog (1978) ont observé qu'en Alberta, les femelles, au cours de l'incubation des oeufs, s'alimentent presque exclusivement des aiguilles des nouvelles pousses d'ÉpINETTE blanche dans des forêts dominées par le Pin lodgepole. Pendergast et Boag (1971) suggèrent que cette préférence résulterait d'un besoin alimentaire riche en calcium pendant et après la période de production des oeufs. Selon ces mêmes auteurs, les pousses d'ÉpINETTE blanche posséderaient une quantité de calcium significativement plus élevée que celle retrouvée dans le Pin lodgepole (espèce dominante). Ellison (1966) n'a toutefois pas observé, en Alaska, de différence significative entre l'ÉpINETTE blanche et l'ÉpINETTE noire relativement au taux de calcium.

Succès de nidification

Le taux de succès de la nidification observé dans l'île d'Anticosti se rapproche de ce qui est rapporté pour la même sous-espèce (*F. c. canadensis*) au Nouveau-Brunswick (81%) (Redmond et al. 1982). Il est par contre supérieur à la valeur de 30 p. cent, rapportée par Keppie et Herzog (1978) pour la sous-espèce *F. c. franklinii* en Alberta. La même tendance s'observe pour le nombre d'oeufs et, il semble que la période moyenne d'incubation enregistrée au cours de notre étude est sensiblement la même que celle observée par McCourt et al. (1973) pour la sous-espèce *F. c. franklinii*. Nos données sur la durée de l'incubation chez *F. c. canadensis* semble être les premières rapportées dans la littérature pour cette sous-espèce.

Conclusion

Les tétras introduits dans l'île d'Anticosti ont sélectionné comme habitat des sites comparables à ceux utilisés par des populations continentales bien établies. De plus, les données relatives au succès reproducteur se comparent avantageusement à ce qui est rapporté pour ces populations. Ces résultats permettent de croire que l'introduction du Tétras du Canada dans l'île d'Anticosti est une réussite, ce que confirment les observations recueillies depuis dix ans.

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New or Rediscovered Native Vascular Plant Species in British Columbia

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Douglas, George W., Frank Lomer, and Hans L. Roemer. 1998. New or rediscovered native vascular plant species in British Columbia. *Canadian Field-Naturalist* 112(2): 276-279.

Fourteen taxa new to British Columbia and three others recently rediscovered are discussed. Seven of the new species also represent first records for Canada.

Key Words: Native vascular plants, new records, rediscovered species, British Columbia, Canada.

Plant collections by the authors in British Columbia during recent years continue to reveal new and interesting taxa. This paper supplements the previously known flora (Douglas et al. 1989, 1990, 1991, 1994) and documents the occurrence of fourteen native vascular plant species new to British Columbia, including four overlooked species (*Botrychium crenulatum*, *Minuartia macrocarpa*, *M. stricta* and *M. yukonensis*) and seven new to Canada. Three rediscovered species are also discussed. The total number of taxa in British Columbia, in addition to those tallied by Douglas (1994), now stands at 2872, including 2319 native plants.

The specimens cited are deposited in one or more of the following herbaria: Agriculture Canada, Ottawa (DAO), University of British Columbia (UBC), and Royal British Columbia Museum (V). First records for Canada are designated by an asterisk.

Species New to British Columbia

**Antennaria flagellaris* (A. Gray) A. Gray, Stolinous Everlasting.

This species was previously known from northern Wyoming and central Oregon north to central Washington (Cronquist 1955). In 1996, and again in 1997, it was collected near Whipsaw Creek in southern British Columbia, 49°24'N 120°34'W (Lomer 96-178 [UBC], 97-082 [V] and 97-086 [V]).

Arnica longifolia Dougl. ex Hook., Seep-spring Arnica.

Although this species was known from a number of collections along the British Columbia border in Alberta, Washington and Montana (Maguire 1943; Cronquist 1955; Douglas 1982;

Packer 1983), it was not collected in British Columbia until 1994. The latter collection was made at Harry Lake in southern British Columbia, 49°04'N 119°53'W (Martin & Douglas 94864 [V]).

**Botrychium crenulatum* W.H. Wagner, Dainty Moonwort.

This species was described by Wagner and Wagner (1981) and later treated in *The Flora of North America* (Wagner and Wagner 1993) as occurring from southern California north to southeastern Washington, northern Idaho and Montana. Since British Columbia was not included in the range of the species, a 1959 collection from Three Mile Lake, Flathead River area (identified by W. H. Wagner), in extreme southeastern British Columbia, represents the first record for British Columbia, 49°21'N 114°37'W (Bell & Davidson 749 [DAO]). A second collection (also identified by W. H. Wagner) was made at Mill Creek, west of Fort Nelson in northeastern British Columbia in 1960, 58°41'N 123°57'W (Calder & Kukkonen 27302 [DAO]).

**Carex vallicola* Dewey, Valley Sedge.

This species was formerly known to occur from southern Utah and southern Nevada north to Okanogan County, Washington (Hitchcock et al. 1969; Washington Natural Heritage Program 1994). A first record for British Columbia was made in the Ashnola River Valley, southcentral British Columbia in 1993, 49°08'N 120°05'W (Lomer 93-048 [UBC]). It was later collected in southcentral British Columbia in 1994 and 1995 near Pasulko Lake, 50°24'N 121°32'W (Lomer 94-042 [UBC] and in 1997 near Tracey Lake, 49°23'N 120°34'W (Lomer 97-090 [V], 97-091 [V] and 97-101 [V]).

**Collomia tenella* A. Gray, Diffuse Collomia.

The known range of this species previously extended from Utah and Nevada north to central Idaho and central Washington (Hitchcock et al. 1959). In 1997 the range was extended to the Similkameen River Valley in southcentral British Columbia, 49°24'N 120°33'W (*Lomer 97–156* [UBC]).

Erigeron ochroleucus Nutt. var. *scribneri* (Canby ex Rydb.) Cronq., Buff Daisy.

This species (Figure 1) was previously known from southeastern Alberta and southern Saskatchewan south to Wyoming, North Dakota and Nebraska (Douglas 1995). In 1996 it was collected on Mount Gass, in the Rocky Mountains of southeastern British Columbia, 50°05'N 114°45'W (*Roemer & Penny 96463* [V]).

Hedeoma hispida Pursh, Rough Pennyroyal.

The previous known range of this species extended from southern Alberta east to Quebec and south to Colorado, Texas and Florida (Hitchcock et al. 1959; Packer 1983). It was first collected in 1993 in British Columbia near Horseshoe Lake in southeastern British Columbia, 49°33'N 115°14'W (*Lomer 93–125* [UBC]). During 1994, a second collection was taken at Kikomun Creek Provincial Park in southeastern British Columbia, 49°15'N 115°14'W (*Lomer 94–107* [UBC]).

Minuartia macrocarpa (Pursh) Ostenf. (*Arenaria macrocarpa* Pursh), Large-fruited Sandwort.

This amphiberingian species was previously described as ranging from northeastern Russia through Alaska, Yukon Territory, and northwestern District of Mackenzie (Hultén 1968; Welsh 1974; Porsild and Cody 1980; Cody 1996). The first record for British Columbia was taken in 1979 at Mount Mansfield in northwestern British Columbia, 59°54'N 136°42'W (*Douglas & Ratcliffe 11167* [V]).

Minuartia stricta (Sw.) Hiern., Rock Sandwort.

This circumpolar taxon was previously known to range south in northwestern North America to southern Yukon Territory (Hultén 1968; Cody 1996). It was first collected in British Columbia in 1979 along the Haines Road, northwestern British Columbia, 59°49'N, 136°38'W (*Douglas & Ratcliffe 11114* [V]). Later collections were also made in 1982 at Toad River, northern British Columbia, 59°23'N 123°55'W (*Ceska, Ceska & Goward s.n.* [V]) and Muncho Lake, northern British Columbia, 59°12'N 126°12'W (*Ceska, Ceska & Goward 13422 and 13429* [V]).

Minuartia yukonensis Hulten (*Arenaria laricifolia* auct. non [L.] B.P. Robins.), Yukon Sandwort.

This amphiberingian species ranges from northeastern Russia through Alaska, Yukon Territory

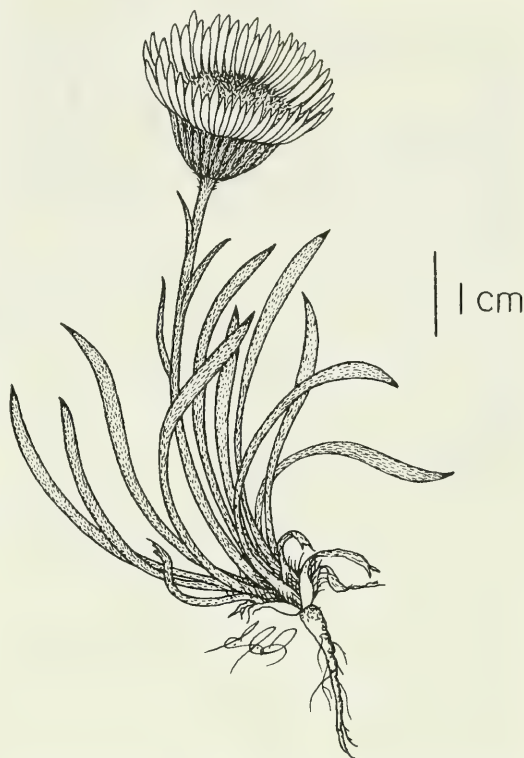


FIGURE 1. Habit of *Erigeron ochroleucus* var. *scribneri*. (Line drawing by Elizabeth J. Stephen in Douglas (1995).

and northwestern District of Mackenzie (Hultén 1968; Welsh 1974; Porsild and Cody 1980; Cody 1996). The first record for British Columbia was taken in 1979 at Mount Mansfield in northwestern British Columbia, 59°54'N 136°42'W (*Douglas & Ratcliffe 11171* [V]). A second record was taken in 1982 at Toad River, northern British Columbia, 59°23'N 123°55'W (*Ceska, Ceska & Goward s.n.* [V]).

Orobancha ludoviciana Nutt. ssp. *ludoviciana*, Suksdorf's Broomrape.

This taxon was previously known to range from Mexico and Texas north to Washington and east to Saskatchewan and Illinois (Hitchcock et al. 1959). In 1993, the first record for the province was collected at Bull River in southeastern British Columbia, 49°28'N 115°26'N (*Lomer 93–149* [UBC]).

**Orthocarpus barbatus* Cotton, Grand Coulee Owl-Clover.

This distinctive species was previously known from a restricted range in central Washington (Hitchcock et al. 1959). It joins 46 other species as a

1996). It was collected east of Osoyoos in southcentral British Columbia in 1994, 49°00'N 119°24'W (Douglas & Illingworth 12848 [UBC, V]). It was later collected in 1996 near the latter site (Lomer 96-079 [UBC]) and in 1995 and 1997 just south of Osoyoos, 49°01'N 119°30'W (Lomer 95-198 [V] and 97-124 [V]). In 1997, it was collected at a third site south of Osoyoos, 49°01'N 119°30'W (Lomer 97-123 [V]).

**Psilocarphus brevissimus* Nutt. var. *brevissimus*, Dwarf Woolly-heads.

Known previously from Mexico and California north to western Montana and eastern Washington (Cronquist 1955). In 1996, and again in 1997, this species was collected near Whipsaw Creek in southern British Columbia, 49°23'N 120°34'W (Lomer 96-177 [UBC], 97-076 [V], 97-079 [V], and 97-151 [V]).

Senecio cymbalaria Pursh. (*S. resedifolius* Less.), Northern Butterweed.

This amphiberian species previously was known to range from northeastern Russia east to Alaska, Yukon Territory and western District of Mackenzie as well as being disjunct in Quebec and Newfoundland (Hultén 1968; Porsild and Cody 1980; Cody 1996). It is now known from Matheson Inlet, Queen Charlotte Islands, from a 1979 collection, 131°30'N 52°26'W (Roemer 79134 [V]).

**Trichostema oblongum* Benth., Mountain Bluecurls.

This species was previously known from California and Nevada north to eastern Washington and adjacent Idaho (Hitchcock et al. 1959). In 1996 it was collected near Castlegar in southeastern British Columbia, 49°17'N 117°47'W (Roemer 96163 [V]).

Species Recently Rediscovered in British Columbia

Aster frondosus (Nutt.) A. Gray (*Brachyactis frondosa* [Nutt.] A. G. Jones), Alkali Aster.

Until recently, a collection in 1939 at Osoyoos in southeastern British Columbia (Eastham 6122 [UBC]) was the only known record of this species in the province (Eastham 1947). The species was recollected on the east side of Osoyoos Lake in 1993, 49°03'N 119°28'W (Lomer 93-281 [UBC]) and again in 1994 (Douglas 13081 [UBC, V]).

Astragalus vexilliflexus Sheld. var. *vexilliflexus*, Bent-flowered Milk-vetch.

This taxon, although reported for British Columbia by Hitchcock and Cronquist (1961), Taylor (1974), Taylor and MacBryde (1977), and Scoggan (1978), was apparently never represented by a voucher specimen. Therefore, it was excluded from the British Columbia flora by Straley et al.

(1985) and Douglas et al. (1990). Material collected in 1996 in southeastern British Columbia at Mt. Gass, 50°05'N 114°43'W (Roemer & Penny 96471 [V]) McLatchie Creek, 49°22'N 114°40'W, (Roemer & Walker 96210 [V]) and Cabin Pass, 49°08'N 114°44'W (Roemer & Walker 96223) now verifies the species for British Columbia.

Cimicifuga elata Nutt., Tall Bugbane

This species was collected in 1957 on Mount Liumchen, southwestern British Columbia, 49°00'N 121°54'W (Beamish 7928 [UBC]). It was not until 39 years later, in 1996, that another collection of the species was made nearby at Cultus Lake, 49°04'N 122°00'W (Douglas, Penny & Wentworth 13231 [V]). It has also come to our attention that several other observations of this species were made in the same area in the 1980s but no vouchers were taken (R. Scagel, personal communication).

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Status of the Water-plantain Buttercup, *Ranunculus alismifolius* var. *alismifolius* (Ranunculaceae) in Canada*

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Douglas, George W., and Jeanne M. Illingworth. 1998. Status of the Water-plantain Buttercup, *Ranunculus alismifolius* var. *alismifolius* (Ranunculaceae) in Canada. *Canadian Field-Naturalist* 112(2): 280–283.

In Canada, *Ranunculus alismifolius* var. *alismifolius* has been documented from collections at four sites, all restricted to southeastern Vancouver Island and an adjacent small island in British Columbia. Two of these sites were recorded at vague locations and are either extirpated or are earlier records of one of the extant sites. The two extant locations (Uplands Park near Victoria and Ballenas Island near Nanaimo) represent the northern range limits of *R. alismifolius* var. *alismifolius* which extends southward to northern California. This plant inhabits open moist, often muddy, ephemeral sites and is limited to a lowland *Quercus garryana*-*Bromus* meadow and a depression on a windswept rock outcrop. The Uplands Park populations are divided between two small groups, both which exist alongside footpaths within a regional park, making them vulnerable to trampling or destruction from park management activities. Other threats include habitat limitation, fire suppression, and competition from introduced species. While these populations are protected to a certain extent by their location within a regional park, there is no specific legislation for the protection of rare and endangered vascular plants in British Columbia. The Ballenas Island population has no threats at present since it is an unoccupied private island. Since the total number of known individuals is less than 100, and with little knowledge of the plant's biological and ecological requirements, this variety is susceptible to extirpation.

Key Words: Water-plantain Buttercup, *Ranunculus alismifolius* var. *alismifolius*, endangered, distribution, population size, British Columbia.

The Water-plantain Buttercup, *Ranunculus alismifolius* Geyer ex Bentham var. *alismifolius*, is a member of a genus of about 250 species known worldwide, particularly in the northern temperate zones and tropical mountains (Wilken 1993). It is one of 35 species occurring in British Columbia (Douglas 1991) and about 47 occurring in Canada (Scoggan 1978). This species is not known to have any medicinal or economic uses.

Hitchcock et al. (1964) recognized five varieties of *R. alismifolius* consisting of var. *alismifolius*, var. *montanus* Wats., var. *hartwegii* (Greene) Jeps., var. *davisii* Benson and var. *alismellus* Gray. These authors noted that var. *montanus* appeared somewhat intergradient to var. *alismellus*, while the varieties *montanus*, *hartwegii* and *davisii* were especially intergradient and only slightly dissimilar. In later treatments Wilkens (1993) and Kartesz (1994) recognized only four varieties, merging var. *hartwegii* with var. *alismifolius*.

Ranunculus alismifolius var. *alismifolius* is a leafy, perennial herb from a fibrous to slightly tuberous-based, non-tomentose root (Figure 1). The three to five erect stems arise from the base and are somewhat hollow and from 30 to 60 cm tall. The basal leaves are broadly lanceolate or ovate, often toothed, 4 to 12 cm long, mostly one to three cm wide and usually narrowed to distinct petioles. The cauline leaves are alternate or opposite, entire, linear to narrowly lanceolate and short-petiolate to sessile in the terminal inflorescences. The solitary flowers are yellow with five petals, 8 to 10 mm long and five sepals. The fruits consist of 10 to 60, usually glabrous achenes with straight stout beaks.

Distribution

Ranunculus alismifolius var. *alismifolius* is known in North America from southwestern British Columbia, southward on both sides of the Cascade Mountains through Washington, Idaho, and western Montana to Oregon and northeastern California (Douglas 1991; Hitchcock et al. 1964; Wilken 1993). Of the four or five varieties of *R. alismifolius* known to exist in the Pacific Northwest, only var. *alismifolius* is known from British Columbia and is limited in Canada to Ballenas Island and Uplands Park on

*This paper is based primarily on a COSEWIC status report by the authors. It has been revised to include more recent information. The species was designated endangered by COSEWIC in April 1996. Reports are available from the COSEWIC Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada.



FIGURE 1. Habit of *Ranunculus alismifolius* var. *alismifolius*.

the southeastern tip of Vancouver Island (Figure 2). These British Columbia sites are approximately 300 to 420 km west of the eastern Washington and Idaho sites, respectively, and about 150 km north of the western Washington sites.

Habitat

In North America, *Ranunculus alismifolius* var. *alismifolius* is known to inhabit open moist sites ranging from muddy ditches, pond margins and streambanks to swales and moist alpine meadows (Benson 1952; Douglas 1991; Wilken 1993). In Canada, this taxon is known from a lowland Garry Oak-Brome (*Quercus garryana*-*Bromus*) meadow complex in Uplands Park. This large meadow complex is characterized by deep brunisolic soils and dotted periodically by rock outcrops. It is usually flooded during winter, muddy in the spring, and dry during summer. The site contains open stands of *Quercus garryana* with a substantial variety of forbs including White Hyacinth (*Triteleia hyacinthina*), Western Buttercup (*Ranunculus occidentalis*) and Common Camas (*Camassia quamash*) but tends to be dominated by grasses such as Orchardgrass (*Dactylis glomerata*), Sweet Vernalgrass (*Anthoxanthum odoratum*), and several species of

Bromus. Some stands are dominated in the understorey by shrubs, in particular, Snowberry (*Symphoricarpos albus*) and Scotch Broom (*Cytisus scoparius*), which shade out many herbaceous species.

On Ballenas Island this taxon grows on shallow soil in a depression on a rock outcrop. This ephemeral site is wet during the spring and windswept for most of the year. A species of sedge (*Carex* sp.) is the most common associate.

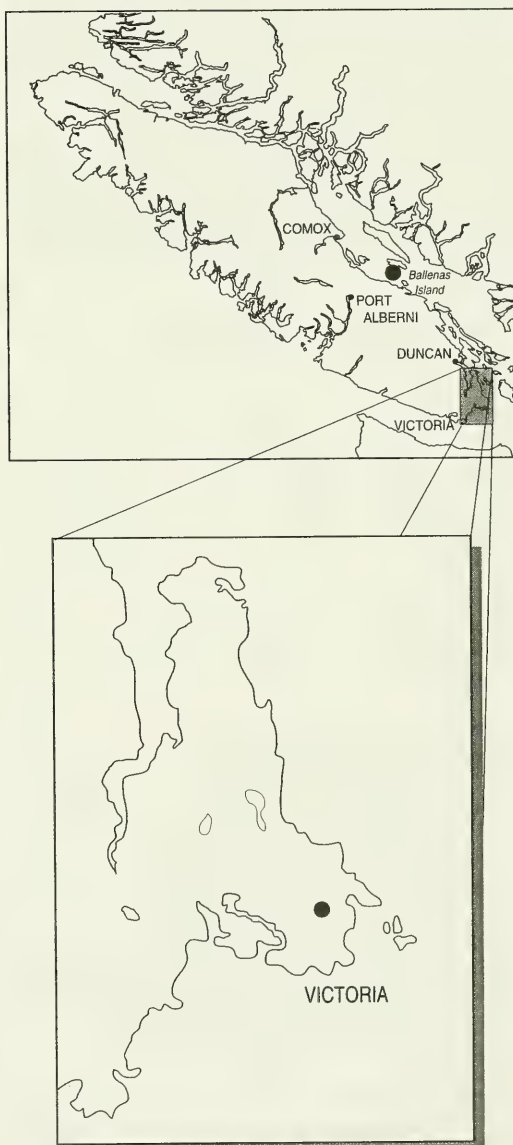


FIGURE 2. Distribution (•) of *Ranunculus alismifolius* var. *alismifolius* in British Columbia.

General Biology

Other than general habitat information, there are few details in the literature regarding the biology and ecology of *Ranunculus alismifolius* var. *alismifolius*. This includes many aspects of the population dynamics such as the average life-span of the variety, the frequency and requirements for seed germination, and the competitive ability of *R. alismifolius* var. *alismifolius* with other species. It is likely, however, that this plant shares many of the same traits that are typical of the genus.

Like many other herbs that occur in grass-dominated meadows, this perennial appears to take advantage of the high light levels and warm, moist conditions found during spring. Surrounding vegetation, particularly the grasses, are also shorter during this period allowing the herbs full benefit of the light levels and greater space. Vegetative growth occurs in muddy areas in early spring with flowers of *R. alismifolius* var. *alismifolius* emerging in April and May. Seed maturation occurs in June, with each head producing 30 to 50 achenes. During July, when drought conditions are prevalent in the meadow, the plants are senescent and remain dormant until the following year.

Since *Ranunculus alismifolius* var. *alismifolius* does not appear to reproduce by other means, seed production is likely to be of critical importance to the maintenance and spread of this species into new habitats. Given the bright yellow appearance of the flower, and the presence of a pocket-like nectary gland, it is likely that insects are the principal pollinators. Leppik (1964) indicated that flowers of *Ranunculus* were visited by a wide variety of insects including bees, flies, butterflies, beetles and ants. The resulting seeds do not appear to be easily dispersed. Although not specifically documented, the size and shape of the achenes indicate dispersal is probably achieved by birds and small animals.

Population Size and Trends

Ranunculus alismifolius var. *alismifolius* has recently been monitored only at the Uplands Park site near Victoria. Between 1991 and 1997, the smallest population has remained relatively stable in numbers and size, ranging from 15 to 18 plants over 1 to 2 m². The second population at this site has increased in numbers and size (during the same time period), increasing from 32 to 46 plants over areas of 4 to 7 m². At the Ballenas Island site the single population had 15-20 plants over 50 m² in 1996.

Limiting Factors

The most direct and immediate threat to the extant populations of *Ranunculus alismifolius* var. *alismifolius* is habitat destruction. In spite of the mandate followed by park administrators to treat Uplands

Park as a "natural" habitat, with little active management, there are several examples of park maintenance resulting in the destruction of native, and sometimes rare, plant species. These park "improvements" include the addition of fire hydrants, the planting of exotic Scotch Pine trees (*Pinus sylvestris*) and gravel deposited in areas deemed excessively muddy.

While introduced grasses and forbs may pose an immediate threat to *Ranunculus alismifolius* var. *alismifolius*, this is difficult to judge since nothing is known of the competitive interactions of this species with others. The continued existence of both populations of *R. alismifolius* var. *alismifolius* alongside pathways, where other plants are reduced in size, indicates that this species is a poor competitor.

The sites, because they are located alongside footpaths may also prove detrimental due to the constant risk of being trampled. The municipal park is heavily used by pedestrians, particularly those with dogs, and mountain-bike enthusiasts.

Special Significance of the Species

Ranunculus alismifolius var. *alismifolius* is a member of a relatively small group of species with a restricted Pacific Coast range that have their northern limits in southern British Columbia. The significance of these peripheral populations, especially with respect to their ecological and genetic characteristics, has yet to be studied adequately. This species may prove to be a fruitful subject for genetic research.

Protection

There is no specific legislation for the protection of rare and endangered vascular plants in British Columbia. The British Columbia Conservation Data Centre has ranked this species as S1³ and placed it on the Ministry of Environment, Lands and Parks Red List. This is the most critical category for imperiled rare native vascular plants in the province.

The populations of *Ranunculus alismifolius* var. *alismifolius* at Uplands Park are protected to a cer-

³S ranks, for provincial or state rare elements, are those of The U.S. Nature Conservancy. The ranks are defined as follows:

- S1 - "critically imperiled because of extreme rarity (5 or fewer extant occurrences or very few remaining individuals) or because of some factor(s) making it especially vulnerable to extirpation or extinction".
- S2 - "imperiled because of rarity (typically 6-20 extant occurrences or few remaining individuals) or because of some factor(s) making it vulnerable to extirpation or extinction".
- S3 - "rare or uncommon; (typically 21-100 occurrences); may be susceptible to large-scale disturbances; e.g., may have lost extensive peripheral populations".

tain extent by their location on public property where there is a reduced risk of development within park boundaries. Park maintenance, however, appears to continue with little concern for the effects on rare species. Signs posted at the park entrances prohibiting the use of bicycles seem to go unheeded due to little, if any, enforcement. The population on Ballenas Island, although not threatened at this time could be in danger if development takes place on the island.

Evaluation of Status

Ranunculus alismifolius var. *alismifolius* is considered by COSEWIC and the British Columbia Conservation Data Centre to be endangered in Canada and is known only from two extant colonies restricted to southeastern Vancouver Island and an adjacent island. The prognosis for this species is not good considering the small size of the populations the threats to the populations in Uplands Park.

Acknowledgments

We thank Adolf Ceska for information acquired at the Ballenas Island site and Gail Harcombe for preparation of the map.

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Status of the Coastal Wood Fern, *Dryopteris arguta* (Dryopteridaceae) in Canada*

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Jamison, Judy A., and George W. Douglas. 1998. Status of the Coastal Wood Fern, *Dryopteris arguta* (Dryopteridaceae) in Canada. *Canadian Field-Naturalist* 112(2): 284–288.

In Canada, *Dryopteris arguta* is restricted to southeastern Vancouver Island and several adjacent small islands. Fifteen of the 16 extant sites are on Gulf Islands; all have been either reconfirmed or discovered during the present study. Existing populations represent the northern range limits of *D. arguta*. Only at the Dorcas Point site (north of Nanaimo on Vancouver Island) does direct habitat destruction appear to pose a threat to a *D. arguta* population. *Dryopteris arguta* populations on private property are vulnerable to zoning changes, but fortunately all but one are subject to the bylaws of the Islands Trust, which are conservationist in intent.

Key Words: *Dryopteris arguta*, Coastal Wood Fern, vulnerable, distribution, population size, British Columbia.

Coastal Wood Fern, *Dryopteris arguta* (Kaulf.) Watt, is a member of a cosmopolitan genus of about 150 species that is well represented in North America (Hitchcock et al. 1969; Lellinger 1985). Most North American species of this genus fall into one large biosystematic complex; however, no hybrids between *D. arguta* and other species of North American *Dryopteris* are known. It is one of seven species occurring in Canada (Scoggan 1979) and in British Columbia as well (Ceska 1991).

There does not seem to be any nomenclatural controversy over this species among recent taxonomic treatments (Hitchcock et al. 1969; Scoggan 1979; Argus and Pryer 1990; Douglas et al. *in press*; Kartesz 1994).

Dryopteris arguta is an evergreen, tufted fern with stout, short-creeping rhizomes and somewhat leathery blades, measuring up to 70 cm tall. The stout leaf stalks are about half the length of the blades, which are twice divided with the pinnules oblong and twice serrated (Figure 1). The rhizomes, stipes, and undersides of the pinnae are beset with mostly lance-shaped, bright chestnut-colored scales.

Distribution

Dryopteris arguta occurs along North America's west coast, from southwestern British Columbia, south through Washington, Oregon, California and Baja California, as well as disjunctly in the mountainous region east of Phoenix, Arizona (Taylor 1970; Montgomery and Wagner 1993; Kearney and Peebles 1960). In Canada, it is restricted to southeastern Vancouver Island and several adjacent small islands (Figure 2).

Reports of *D. arguta* from the Victoria area or mainland British Columbia (e.g., Macoun 1890;

Taylor 1971; Cody and Britton 1989) are based on misidentifications of Male Fern (*D. filix-mas*).

Habitat

Dryopteris arguta typically occurs either on coastal wooded slopes in filtered light provided by Douglas-fir (*Pseudotsuga menziesii*), Garry Oak (*Quercus garryana*), and Pacific Madrone (*Arbutus menziesii*), or on rocky coastal cliffs and outcrops where associated light-filtering plants, if present, include Garry Oak and Ocean Spray (*Holodiscus discolor*). Typical understory shrubs in the forested sites include *Holodiscus discolor*, Sword Fern (*Polystichum munitum*), and Oregon Grape (*Mahonia nervosa*). In the more exposed rocky sites, Purple Honeysuckle (*Lonicera hispidula*), Serviceberry (*Amelanchier alnifolia*), and Kinnikinnick (*Arctostaphylos uva-ursi*) were found to be associated with *D. arguta*. Many of these plants are indicators for very dry, fast-draining, nitrogen-medium soils (Klinka et al. 1989). Exposure at the study sites is almost invariably southwestern, southeastern, or southern.

General Biology

Sporophytes of *Dryopteris arguta* often retain significant numbers of mature spores over winter, to be released the following spring (Farrar 1976). Blades of *D. arguta* mature in one to five years, at which time each fertile blade can produce as many as 13.5–15 million spores. *Dryopteris arguta* also grows vegetatively by subterranean rhizome elongation, resulting sometimes in large clumps of clones. In most of the study sites here surveyed, *D. arguta* occurs on dry, sandy, rapidly drained soil; such conditions are not ideal for either spore germination or



FIGURE 1. Illustration of *Dryopteris arguta*. (Line drawing by Lora-May Richards in Douglas et al., *in press*.)

gamete fertilization. Therefore, it can be inferred that most reproduction of *D. arguta* in these sites is by simple rhizome elongation, probably because the species is stressed here at the edge of its range (Walker 1979).

Study locations having robust populations of *Dryopteris arguta*, with numerous juvenile plants, were the coastal wooded slope habitats, where light, soil, and moisture optimize growth conditions. On rocky outcrops and coastal cliffs, with only small pockets of dry mineral soil, exposure to sun and storm, and often crowding, *Dryopteris arguta* populations appear stressed and were reproducing vegetatively, if at all. No prothalli were observed at any site.

Population Size and Trends

There are 18 known British Columbia populations of *D. arguta* in 16 different sites on the southeastern coast of Vancouver Island and several adjacent islands (Table 1). Populations number from one or

two small clumps to several thousand individual plants, depending on the locality. By far the most successful population is a lush band of 3000–4000 plants stretching for about 400 m, on a southeast-facing slope at about 100 m elevation on Hornby Island, forming the dominant understory in a forest of Douglas-fir and Garry Oak. Five sites are poor habitats because of crowding and/or harsh exposure on rocky outcrops, and thus those populations number less than 100 plants.

A concerted effort to locate new populations of *D. arguta* resulted in the recording of six new sites; thus, there is reason to expect that further flourishing populations remain to be discovered — unknown mostly because of their inaccessibility on rocky cliffs or steep forested slopes.

Limiting Factors

Land clearing for development apparently is a distinct threat to the *D. arguta* population at Dorcas

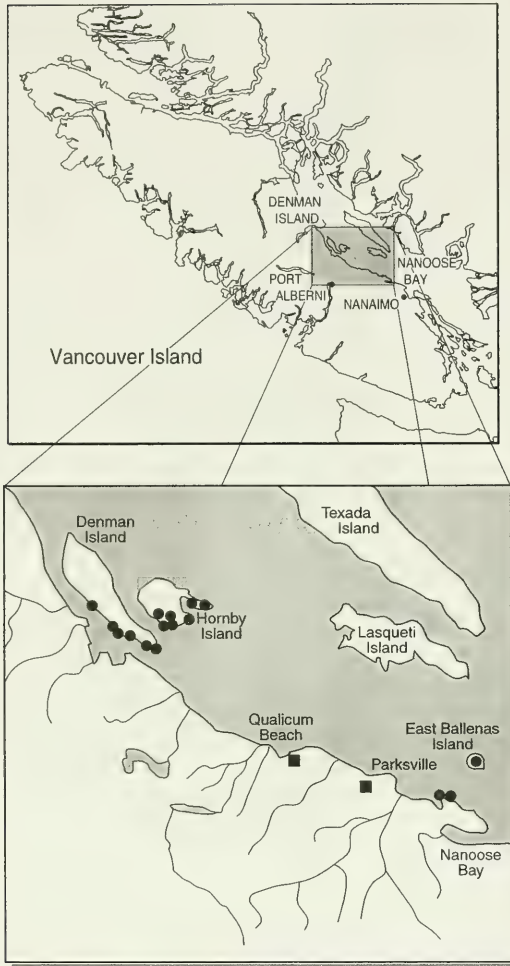


FIGURE 2. Distribution of *Dryopteris arguta* in British Columbia.

Point, which has one of the highest concentrations of privately owned land on Vancouver Island's east coast. Extensive subdivisions have taken place there recently. Populations on the adjacent islands are less directly threatened: those on public lands (Provincial Parks on Denman and Hornby islands and Federal Crown land on East Ballenas Island owned by the Department of National Defence) are protected from development, while island bylaws coupled with islanders' predominantly preservationist attitudes severely limit subdivision of privately-owned land parcels. Recreational use of public areas puts *Dryopteris arguta* populations at risk. A campground on Hornby Island has many seasonal dwellings, resulting in heavy foot traffic. Tourism on Hornby, with the associated pressures of development, is a serious consideration for several other *D. arguta* populations as well. Often park enhancement

TABLE 1. Locations of *Dryopteris arguta* visited by the senior author during 1996.

Collection Site	Population (no./area)
Denman Island	
South of Metcalf Bay	40+ / 100 m ²
South of Buckley Bay ferry landing	60+ / 100 m ²
West of Boyle Point	70 / 100 m ²
West of Boyle Point, Cedar Creek	50+ / 150 m ²
South of Millard Road	150+ / 400 m ²
Repulse Point	300+ / 400 m ²
Hornby Island	
Norman Point, southwest of Ford's Cove	28 / 20 m ²
Norman Point, Heron Rocks	500+ / 1000 m ²
Southwest of Downes Point	21 / 60 m ²
Downes Point	110+ / 50 m ²
Slope above Central Road, north of Heron Rocks	3500+ / 1400 m ²
High Salal Ranch, east of Tribune Bay Park boundary	100+ / 900 m ²
Bluffs northwest of Helliwell Park boundary	60 / 20 m ²
Nanaimo District	
Gerald Island	300+ / 1500 m ²
E. Ballenas Island	70+ / 50 m ²
Nanose Lake District	
Dorcas Point	7 / 10 m ²

projects such as hiking trails at Boyle Point Provincial Park on Denman Island can put *D. arguta* populations at risk.

Natural threats to known extant *D. arguta* populations consist of erosion and exposure from sun, wind, and seasonal storms on the exposed rocky outcrop sites. Several of the Hornby Island populations fall into this category, one at Downes Point and those near Helliwell and Tribune Bay parks. Similar conditions apply on Gerald and East Ballenas islands.

Special Significance of the Species

Unique in Canada, the Coastal Douglas-fir (CDF) biogeoclimatic zone exists unaltered over less than 1% of its total area (PMHL Proposal 1963¹). *Dryopteris arguta* populations in British Columbia deserve protection for their integral understory role in the CDF ecosystem. As evergreens, they make a substantial contribution to the ecosystem's energy balance; furthermore, they reduce erosion in the steep slope situations they very often inhabit.

¹A Proposal for the Protection of the Ballenas and Winchelsea Islands under the Pacific Marine Heritage Legacy (a proposal partnership between the Pacific Marine Heritage Legacy, the Canadian Wildlife Service, Environment Canada, the Department of National Defence, and the Nature Conservancy of Canada).

Dryopteris arguta is part of the red-listed Garry Oak-Arbutus community, represented particularly on Hornby, East Ballenas, and Gerald islands. The latter two islands are in the 19-island Ballenas/Winchelsea Archipelago, which remain relatively pristine due to their isolation and lack of fresh water and are the subject of a proposal for protection under the Pacific Marine Heritage Legacy (PMHL Proposal 1963). This archipelago received the British Columbia Conservation Data Centre's (CDC) highest biodiversity ranking, one of only ten such sites within the Islands Trust area.

Protection

Dryopteris arguta has been globally ranked by the U.S. Nature Conservancy as G5¹. In the southern portion of its range, Oregon and California, it occurs frequently. There is no specific legislation for the protection of rare and endangered vascular plants in British Columbia. The British Columbia Conservation Data Center ranks this species as S2².

Dryopteris arguta occurs rarely in British Columbia in fairly specialized habitats; it is apparently limited to southerly exposures along coastline with milder climates associated with the Japan Current and the rainshadow effect of the Vancouver Island and Olympic Mountains. Mild climate combined with considerable natural beauty are encouraging explosive residential and commercial development, placing existing land preservation statutes under pressure.

Evaluation of Status

Dryopteris arguta is considered by COSEWIC and the British Columbia Conservation Data Centre to be vulnerable in Canada. Because of its restricted distribution and the heavy development pressures that coincide with its limited range, it is sensitive to both natural and anthropogenic forces. Of the 16 known sites, 15 are on small islands in the Straits of Georgia. Most of these (12) are administered by the

Islands Trust, since they are on private land. Only at the Dorcas Point site (north of Nanaimo on Vancouver Island) does accelerating lot subdivision followed by land clearing for development appear to be a direct threat to the *D. arguta* population.

A more realistic approach toward sensible protection of the remaining natural environment would probably be to protect entire ecosystems judged to be vulnerable to human encroachment, rather than targeting one or two species for protection. In the proposal to protect the Ballenas and Winchelsea island archipelago under the Pacific Marine Heritage Legacy, we see a model for implementing the ecosystem approach. Implementation would protect not only the known and possibly yet undiscovered populations of *D. arguta*, but also a uniquely pristine example of the red-listed Garry Oak-Arbutus plant community and several very rare species including the recently discovered Water-plantain Buttercup (*Ranunculus alismifolius* var. *alismifolius*).

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¹Defined as "common to very common; demonstrably secure and essentially ineradicable under present conditions."

²Ranks, for provincial or state rare elements, are those of The U.S. Nature Conservancy and are defined as follows: S1 – "critically imperiled because of extreme rarity (5 or fewer extant occurrences or very few remaining individuals) or because of some factor(s) making it especially vulnerable to extirpation or extinction".

S2 – "imperiled because of rarity (typically 6–20 extant occurrences or few remaining individuals) or because of some factor(s) making it vulnerable to extirpation or extinction".

S3 – "rare or uncommon; (typically 21–100 occurrences), may be susceptible to large-scale disturbances; e.g., may have lost extensive peripheral populations."

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New Records of Vascular Plants in the Yukon Territory

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Cody, William J., Catherine E. Kennedy, and Bruce Bennett. 1998. New records of vascular plants in the Yukon Territory. *Canadian Field-Naturalist* 112(2): 289–328.

Thirteen native taxa including *Alisma plantago-aquatica* var. *americana*, *Carex aquatilis* ssp. *stans*, *C. lenticularis* var. *lipocarpa*, *Cassiope mertensiana*, *Dryopteris carthusiana*, *Lathyrus ochroleucus*, *Lonicera dioica* var. *glaucescens*, *Maianthemum canadense* ssp. *interius*, *Papaver alboroseum*, *Platanthera orbiculata*, *Potamogeton strictifolius*, *Salix raupii* and *Vaccinium membranaceum* are reported new to the known flora of the Yukon Territory. Nine introduced taxa are also reported as new to the known flora. Significant range extensions within the Territory are reported for 287 native and 17 introduced taxa. Most of the range extensions involve the eastern portion of the Territory. Comments are presented on 11 native taxa and two native taxa are deleted from the Territory.

Key Words: Vascular plants, Yukon Territory, flora, new records, range extensions, phytogeography.

The writing of the *Flora of the Yukon Territory* (Cody 1996) was completed in late 1994. During the summers of 1994 and 1995 the Government of the Yukon Territory Department of Renewable Resources contracted surveys in the southeastern part of the Territory. Extensive collections of vascular plants were made during these surveys. Also in 1995, Bruce Bennett, Canadian Wildlife Service, Environment Canada, undertook a survey in this region and again numerous vascular plants were collected. In addition in 1996, Rhonda Rosie made collections in the vicinity of Frances Lake, Greg Brunner in the Dawson-Dempster Highway region and Bruce Bennett again made collections in the southeast in both 1996 and 1997. The result has been the accumulation of much information on the geographic distribution of vascular plants including many new and significant records.

The purpose of the present paper is to update the Yukon Flora by reporting these new records. This additional data will serve as an adjunct to *Flora of the Yukon Territory* (Cody 1996) and improve the amount of data available. This information is essential for biological research in the fields of agriculture, forestry, sustainable resource management, landscape planning, environmental assessment and wildlife management. With the additions of 13 native and 9 introduced species reported here the flora now includes 1134 species. The new native species are all rare (as defined by Douglas et al. 1981) in the Territory.

In order to readily access the taxa treated in the body of this paper, they are first listed by status. These lists are then followed by lists of the same species by family in the order of the *Flora of the Yukon Territory*, with annotations providing perti-

nent information. The alphabetism of families by some modern authors is not followed because this can lead to a confusing mix of totally unrelated taxa. Common names follow Cody (1996) and Douglas et al. (1989, 1990, 1991, 1994). These specimens, which were sent to the senior author for identification and verification, have been incorporated in the vascular plant herbarium maintained by Agriculture and Agri-Food Canada at the Central Experimental Farm, Ottawa (DAO). The majority of localities are mapped in Figure 1.

Synoptic List by Yukon Status Native taxa new to the Yukon Territory: (13)

Alisma plantago-aquatica var. *americana*
Carex aquatilis ssp. *stans*
Carex lenticularis var. *lipocarpa*
Cassiope mertensiana
Dryopteris carthusiana
Lathyrus ochroleucus
Lonicera dioica var. *glaucescens*
Maianthemum canadense ssp. *interius*
Papaver alboroseum
Platanthera orbiculata
Potamogeton strictifolius
Salix raupii
Vaccinium membranaceum

Introduced taxa new to the Yukon Territory: (9)

Astragalus cicer
Centaurea maculosa
Cirsium arvense
Elymus hispidus
Lolium perenne ssp. *perenne*
Rorippa curvipes var. *truncata*
Silene noctiflora
Tanacetum vulgare
Tragopogon dubius

Range extensions of native taxa within the Yukon Territory: (287)

Abies lasiocarpa
Achillea sibirica
Actaea rubra ssp. *arguta*
Adoxa moschatellina
Agoseris aurantiaca
Agrostis exarata
Alopecurus aequalis
Amerorchis rotundifolia
Andromeda polifolia
Androsace septentrionalis
Angelica lucida
Antennaria howellii ssp. *canadensis*
Aquilegia brevistyla
Arabis calderi
Arabis codyi
Arabis divaricarpa var. *divaricarpa*
Arabis kamchatica
Aralia nudicaulis
Arctostaphylos rubra
Arnica griscomii ssp. *frigida*
Arnica lessingii
Aster ciliolatus
Aster sibiricus
Astragalus adsurgens ssp. *robustior*
Astragalus alpinus
Astragalus americanus
Astragalus eucosmus
Athyrium filix-femina var. *cyclosorum*
Barbarea orthoceras
Beckmannia syzigachne
Betula glandulosa
Betula neoalaskana
Botrychium lunaria
Bromus pumpellianus var. *pumpellianus*
Calamagrostis canadensis ssp. *canadensis*
Calamagrostis lapponica
Calamagrostis stricta ssp. *inexpansa*
Calla palustris
Callitriche anceps
Callitriche hermaphroditica
Callitriche verna
Caltha natans
Cardamine bellidifolia
Cardamine pensylvanica
Cardamine pratensis
Carex aurea
Carex brunnescens
Carex buxbaumii
Carex canescens
Carex concinna
Carex consimilis
Carex deweyana
Carex disperma
Carex eleusinoides
Carex foenea
Carex interior
Carex lachenalii
Carex lapponica
Carex lasiocarpa ssp. *americana*
Carex leptalea var. *tayloris*
Carex limosa
Carex loliacea
Carex macloviana

Carex macrochaeta
Carex magellanica ssp. *irrigua*
Carex media
Carex podocarpa
Carex praticola
Carex pyrenaica
Carex rostrata
Carex saxatilis
Carex stylosa
Carex utriculata
Carex vaginata
Castilleja miniata
Castilleja rupii
Chamaedaphne calyculata
Chenopodium capitatum
Cicuta bulbifera
Cicuta virosa
Cinna latifolia
Circaea alpina
Claytonia tuberosa
Corallorhiza trifida
Cornus canadensis
Cornus stolonifera
Crepis elegans
Cryptogramma crispa var. *acrostichoides*
Cryptogramma crispa var. *sitchensis*
Cypripedium passerinum
Cystopteris montana
Danthonia intermedia
Draba borealis
Draba cana
Draba fladnizensis
Draba longipes
Dracocephalum parviflorum
Drosera anglica
Dryas hookeriana
Dryopteris expansa
Elaeagnus commutata
Eleocharis acicularis
Eleocharis palustris
Elymus calderi
Epilobium angustifolium
Epilobium hornemannii
Epilobium lactiflorum
Equisetum fluviatile
Equisetum palustre
Equisetum pratense
Equisetum scirpoides
Equisetum sylvaticum
Equisetum variegatum
Erigeron acris ssp. *politus*
Erigeron humilis
Erigeron philadelphicus
Eriophorum angustifolium
Eriophorum gracile
Eriophorum russeolum var. *albidum*
Eriophorum vaginatum
Eriophorum viridi-carinatum
Eutrema edwardsii
Festuca altaica
Festuca brachyphylla
Galium brandegei
Galium trifidum
Gentiana glauca
Gentianella amarella ssp. *acuta*

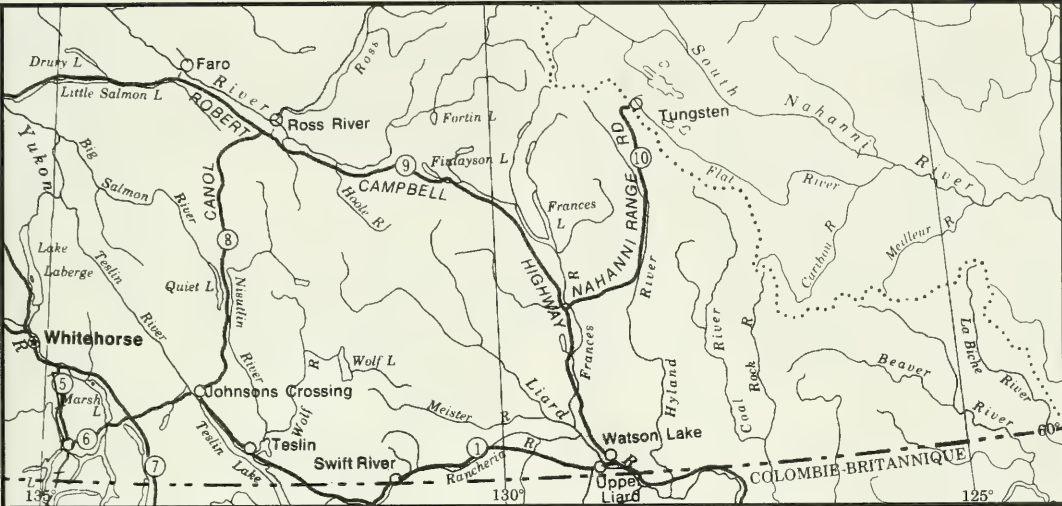


FIGURE 1. Map of southeastern Yukon Territory depicting the areas from whence most cited specimens were collected. The dotted line separates the Yukon Territory from the District of Mackenzie, Northwest Territories.

- Gentianella propinqua* ssp. *propinqua*
- Geranium bicknellii*
- Geum macrophyllum* ssp. *perincisum*
- Geum triflorum*
- Glyceria borealis*
- Glyceria grandis*
- Goodyera repens*
- Gymnocarpium dryopteris* ssp. *dryopteris*
- Heracleum lanatum*
- Hieracium gracile*
- Hieracium triste*
- Hieracium umbellatum*
- Hierochloë alpina*
- Hippuris vulgaris*
- Juncus balticus* var. *alaskanus*
- Juncus castaneus*
- Juncus filiformis*
- Juncus stygius* ssp. *americanus*
- Kobresia sibirica*
- Larix laricina*
- Ledum decumbens*
- Lemna minor*
- Lemna trisulca*
- Lepidium bourgeauanum*
- Leymus innovatus*
- Limosella aquatica*
- Listera cordata*
- Loiseleuria procumbens*
- Luzula arcuata* ssp. *unalaschkensis*
- Luzula confusa*
- Luzula wahlenbergii*
- Lycopodium complantum*
- Lycopodium selago*
- Maianthemum trifolium*
- Matteuccia struthiopteris* var. *pensylvanica*
- Mertensia paniculata* var. *paniculata*
- Minulus guttatus*
- Minuartia biflora*

- Moehringia lateriflora*
- Moneses uniflora*
- Myosotis alpestris* ssp. *asiatica*
- Myriophyllum sibiricum*
- Myriophyllum verticillatum*
- Oplopanax horridus*
- Oryzopsis asperifolia*
- Oryzopsis pungens*
- Osmorhiza depauperata*
- Oxyria digyna*
- Oxytropis campestris* ssp. *varians*
- Oxytropis deflexa* ssp. *sericia*
- Oxytropis splendens*
- Parnassia kotzebuei*
- Pedicularis lanata*
- Pedicularis langsдорffii* ssp. *arctica*
- Petasites frigidus* ssp. *frigidus*
- Petasites frigidus* ssp. *nivalis*
- Phalaris arundinacea*
- Plantago canescens*
- Platanthera obtusata*
- Poa arctica*
- Poa glauca*
- Poa leptocoma*
- Poa palustris*
- Poa porsildii*
- Poa pratensis* ssp. *alpigena*
- Podistera macounii*
- Podistera yukonensis*
- Polygonum caurianum*
- Potamogeton alpinus* ssp. *tenuifolius*
- Potamogeton filiformis* var. *borealis*
- Potamogeton gramineus*
- Potamogeton obtusifolius*
- Potamogeton zosteriformis*
- Potentilla diversifolia*
- Potentilla hyperarctica*
- Potentilla nivea*

Potentilla palustris
Potentilla uniflora
Primula eximia
Primula mistassinica
Pulsatilla ludoviciana
Pyrola grandiflora
Pyrola minor
Ranunculus eschscholtzii
Ranunculus gmelinii ssp. *purshii*
Ranunculus hyperboreus
Ranunculus lapponicus
Ranunculus macounii
Ranunculus sceleratus ssp. *multifidus*
Rhododendron lapponicum
Ribes glandulosum
Ribes hudsonianum
Ribes lacustre
Rubus arcticus ssp. *acaulis*
Rubus arcticus ssp. *arcticus*
Rubus chamaemorus
Rubus pubescens
Rumex maritimus ssp. *fueginus*
Salix alaxensis var. *alaxensis*
Salix arbusculoides
Salix arctica
Salix athabascensis
Salix barclayi
Salix brachycarpa ssp. *brachycarpa*
Salix commutata
Salix drummondiana
Salix exigua ssp. *interior*
Salix lanata ssp. *richardsonii*
Salix maccalliana
Salix myrtilifolia
Salix novae-angliae
Salix pedicellaris
Salix polaris
Salix prolixa
Salix pyrifolia
Salix reticulata ssp. *reticulata*
Salix scouleriana
Sanguisorba officinalis
Saxifraga caespitosa
Saxifraga flagellaris ssp. *setigera*
Saxifraga hieracifolia
Saxifraga hirculus
Saxifraga lyallii ssp. *hultenii*
Saxifraga nelsoniana ssp. *porsildiana*
Saxifraga serpyllifolia
Saxifraga tricuspidata
Scheuchzeria palustris ssp. *americana*
Schizachne purpurascens
Scirpus microcarpus
Scutellaria galericulata var. *pubescens*
Senecio lugens
Senecio pauciflorus
Senecio yukonensis
Sium suave
Solidago canadensis var. *salebrosa*
Solidago simplex
Sparganium angustifolium
Sparganium minimum

Sparganium multipedunculatum
Spiraea beauverdiana
Stellaria borealis
Stellaria calycantha
Stellaria longifolia
Streptopus amplexifolius ssp. *americanus*
Tofieldia coccinea
Trientalis europaea
Trisetum spicatum
Utricularia minor
Vaccinium caespitosum
Vaccinium ovalifolium
Vaccinium vitis-idaea ssp. *minus*
Vahlodea atropurpurea ssp. *latifolia*
Valeriana sitchensis
Veronica wormskjoldii
Vicia americana
Viola adunca
Viola canadensis ssp. *rydbergii*
Viola epipsila ssp. *repens*
Viola nephrophylla

Range extensions of introduced taxa within the Yukon Territory: (17)

Agrostis scabra var. *geminata*
Brassica rapa
Bromus carinatus
Bromus inermis
Cerastium fontanum ssp. *triviale*
Crepis tectorum
Galeopsis tetrahit var. *bifida*
Lolium perenne ssp. *perenne*
Medicago sativa
Melilotus alba
Melilotus officinalis
Plagiobothrys scouleri
Poa annua
Poa pratensis
Sonchus arvensis ssp. *uliginosus*
Thlaspi arvense
Trifolium repens

Comments on native taxa in the Yukon Territory: (10)

Alyssum americanum
Arabis calderi
Arabis codyi
Arabis murrayi
Carex glareosa
Carex marina
Carex subspathacea
Elatine triandra
Pedicularis macrodonta
Poa arctica ssp. *caespitans*

Possible future addition of native taxon to the Yukon Territory: (1)

Polystichum kruckebergii

Deletions of native taxa from the Yukon Territory: (2)

Polystichum braunii
Polystichum munitum

Annotated List by Family

LYCOPODIACEAE

Lycopodium complantum L., Flatbranch Clubmoss — YUKON: dry sedimentary rock outcrop adjacent to Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-270, 11 June 1997 (DAO); upper abandoned gas line on mountain, La Biche River, 60°08'55"N 124°03'32"W, *B. Bennett* 95-247b, 16 June 1995 (DAO).

In southeastern Yukon, Cody (1996) knew this species only as far east as 127°25'W. The sites reported above extend the known range about 190 kilometers further east. *Lycopodium complantum* is however known from the Fort Liard area in nearby southwestern District of Mackenzie (Porsild and Cody 1980).

Lycopodium selago L., Mountain Clubmoss — YUKON: boulder field on south-facing alpine slope, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3141, 6 Aug. 1994 (DAO).

Cody (1996) knew this widespread species in the Yukon Territory only as far east as about longitude 127°W near the District of Mackenzie border. The collection cited above extends the known range about 200 kilometers to the southeast.

EQUISETACEAE

Equisetum fluviatile L., Water Horsetail — YUKON: clay soil at edge of beaver pond, La Biche River, 60°08'59"N 124°03'37"W, *B. Bennett* 95-250b, 16 June 1995 (DAO).

In southeastern Yukon, Cody (1996) knew this species only from as far east as 127°21.5'W. The site reported above lies about 175 kilometers further east; however, *Equisetum fluviatile* is known from the Liard River valley in southwestern District of Mackenzie (Porsild and Cody 1980).

Equisetum palustre L., Marsh Horsetail — YUKON: roadside ditch with *Typha*, La Biche River, 60°04'41"N 124°02'57"W, *B. Bennett* 95-222, 14 June 1995 (DAO).

The specimen cited above is an extension of the known range of about 200 kilometers eastward in the Territory. It is, however, known in the Liard River valley in southwestern District of Mackenzie.

Equisetum pratense Ehrh., Meadow Horsetail — YUKON: open *Picea glauca*/shrub-rich/feathermoss forest, *C. Zoladski et al.*, 16 Aug. 1995 (DAO); Beaver River, 60°11'N 125°09'W, *G. Brunner* 16-28-2, 10 Aug. 1994 (DAO); La Biche River area, 60°33'N 124°32'W, *G. Brunner* 150-33-1, 8 Aug. 1994 (DAO).

The specimens cited above extend the known range in the Yukon Territory about 175 kilometers east of longitude 127°15'W.

Equisetum scirpoides Michx., Dwarf Scouring-rush — YUKON: riverside mud, Lower Beaver River,

60°02'N 124°31'40"W, *B. Bennett* 97-171, 9 June 1997 (DAO); La Biche camp, 60°03'07"N 124°04'03"W, *B. Bennett* 97-304, 13 June 1997 (DAO); spruce bog, Beaver River-Larsen Creek area, 60°10'20"N 125°02'19"W, *B. Bennett* 95-293b, 19 June 1995 (DAO).

The specimens cited above are an extension of the known range of about 175 kilometers eastward in the Territory. It is, however, widespread in the Territory.

Equisetum sylvaticum L., Woodland Horsetail — YUKON: open mature forest, La Biche River, 60°03'45"N 124°01'51"W, *B. Bennett* 95-122a, 6 June 1995 (DAO); La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-114a, 5 June 1995 (DAO).

In southeastern Yukon, Cody (1996) knew this species only from adjacent to the Nahanni Range Road and just west of Watson Lake. The specimens cited above were from an area about 275 kilometers to the east, however *Equisetum sylvaticum* is known from the Liard River valley in southwestern District of Mackenzie (Porsild and Cody 1980).

Equisetum variegatum Schleich., Variegated Horsetail — YUKON: silty shady soil in *Salix exigua* thicket, La Biche River, 60°03'51"N 124°03'W, *B. Bennett* 95-176, 12 June 1995; river-side mud, Lower Beaver River, 60°01'30"N 124°31'40"W, *B. Bennett* 97-175, 10 June 1997 (DAO); Toobally Lake, 60°12'N 126°20'W, *G. Brunner* 333-58-1, 13 July 1994 (DAO).

In southeastern Yukon, Cody (1996) knew this species only from as far east as the Coal River springs (60°09'N 127°25'W). The sites reported above extend the known range about 180 kilometers to the east.

OPHIOGLOSSACEAE

Botrychium lunaria (L.) Sw., Moonwort — YUKON: in open *Pinus contorta* forest, burnt in the 1950s, Beaver River-Larsen Creek area, 60°10'35"N 125°03'22"W, *B. Bennett* 95-281, 18 June 1995; dry graminoid meadow with *Festuca altaica*, ca. 2 kilometers SE of Gusty Lakes helicopter landing point, 60°24.49'N 126°25.59'W, *Staniforth & Wilhelm*, 16 Aug. 1995 (DAO).

This species is localized, but perhaps overlooked in the Yukon Territory, as far north as the Babbage River. The nearest locality in the southeast is in the vicinity of Frances Lake, about 250 kilometers northwest of the localities cited above.

PTERIDACEAE

Cryptogramma crispa (L.) R.Br. var. *acrostichoides* (R.Br.) C.B. Clarke, Mountain-parsley — Hyland River, 61°22'N 128°21'W, *G. Brunner* 119-31-1, 26 July 1994 (DAO).

Cody (1996) knew this fern variety from only four locations in the Yukon Territory. The specimen cited

above is from about 225 kilometers southeast of a location adjacent to the Canol Road and 175 kilometers northeast of a location by the Alaska Highway.

Cryptogramma crispa (L.) R.Br. var. *sitchensis* (Rupr.) C. Chr., Mountain-parsley — YUKON: in crevices on rocky southeast-facing outcrop, Mount Haldane, approx. 63°52'N 135°46'W, R. Rosie 1851, 15 July 1986 (DAO).

Cody (1996) knew this rare fern variety only from the Canol Road about 280 kilometers to the southeast and east southeast.

ASPIDACEAE

Athyrium filix-femina (L.) Roth var. *cyclosorum* (Ledeb.) Moore, Lady Fern — YUKON: uncommon in shaded open flat *Picea glauca*/*Betula papyrifera* forests, Lower Beaver River, 60°02'N 124°31'W, B. Bennett 97-160, 9 June 1997 (DAO); mature spruce forest, La Biche River, 60°03'21"N 123°59'52"W, B. Bennett 95-202, 13 June 1995 (DAO); in lush Balsam Poplar/*Heracleum lanatum* wood near warm spring, Frances Lake, 61°34'N 129°26'W, R. Rosie 1940, 18 July 1996 (DAO).

This fern, which was considered rare in the Yukon Territory by Douglas et al. (1981), was known in the southeast to Cody (1996) only from the Coal River springs, 60°09'N 127°25'W. The specimens cited above are from localities about 260 kilometers to the east and 150 kilometers to the north/northwest.

Cystopteris montana (Lam.) Bernh., Mountain Bladder Fern — YUKON: shady mature White Spruce forest, La Biche River, B. Bennett 95-217b, 14 June 1995 (DAO).

Cody (1996) knew this fern species in the Yukon Territory only as far east as near Teslin Lake. The specimen cited above is from an area about 575 kilometers to the east. Eastward, it is known from southwestern District of Mackenzie (Porsild and Cody 1980).

Dryopteris carthusiana (Vill.) H.P. Fuchs (*D. spinulosa* (O.F. Muell.) Watt), Spinulose Wood Fern — YUKON: along the stream from the spring source to the terraces, Coal River springs and adjacent areas, 60°09'N 127°25'W, Scotter & Ahti 24468, 24472, 24482, 16-19 July 1977 (DAO); shady mature White Spruce forest, La Biche River, 60°03'32"N 123°59'31"W, B. Bennett 95-217a, 14 June 1995 (DAO); La Biche River, B. Bennett 95-141a, 8 June 1995 (DAO).

Cody and Britton (1989) mapped the Coal River specimens cited above, but without comment. Although already described and keyed in Cody (1996) this species is new to the flora of the Yukon Territory and should be added to the list of rare plants (Douglas et al. 1981).

Dryopteris expansa (Presl) Fraser-Jenkins & Jermy, Northern Wood Fern — YUKON: in lush Balsam

Poplar/*Heracleum lanatum* woods near warm spring, Frances Lake, 61°34'N 129°26'W, R. Rosie 1939, 18 July 1996 (DAO); uncommon in shaded, flat *Picea glauca*/*Betula papyrifera* forest, Lower Beaver River 60°02'N 124°31'40"W, B. Bennett 97-168, 9 June 1997 (DAO); shady *Salix*/*Alnus crispa* thicket on hillside, Upper Gaswell, 60°07'15"N 124°06'02"W, B. Bennett 97-292, 19 June 1997 (DAO).

The specimens cited above are an extension of the known range in the Yukon Territory of about 375 kilometers to the east and southeast from sites by the Canol Road.

Gymnocarpium dryopteris (L.) Newm. ssp. *dryopteris* (*Dryopteris disjuncta* Am. auth.), Oak Fern — YUKON: shady *Picea glauca* forest, Lower Beaver River, 60°02'N 124°31'W, B. Bennett 97-257, 10 June 1997 (DAO); La Biche River, 60°03'45"N 124°01'51"W, B. Bennett 95-119b, 5 June 1995 (DAO); on rotten *Populus balsamifera*, La Biche River, 60°03'33"N 124°01'42"W, B. Bennett 95-129b, 7 June 1995; Mount Merrill, 60°04'N 124°44'W, R. Mueller 227-22-6, 9 Aug. 1994 (DAO).

In southeastern Yukon Territory, Cody (1996) knew this fern only from near Watson Lake and adjacent to the Canol Road. The Mount Merrill and La Biche River sites reported above are about 275 kilometers east of Watson Lake. To the east in the District of Mackenzie it is known in the Liard River valley and Mackenzie mountains.

Matteuccia struthiopteris (L.) Todaro var. *pensylvanica* (Willd.) Morton, Ostrich Fern — YUKON: shady *Picea glauca*/*Betula papyrifera* forest, Lower Beaver River, 60°02'N 124°31'W, B. Bennett 97-237, 9 June 1997 (DAO); open disturbed clearing near upper gas well, La Biche River, 60°06'34"N 124°05'39"W, B. Bennett 95-123A, 6 June 1995 (DAO).

This rare plant in the Yukon Territory was previously known only from a single collection at hot springs along the Beaver River (Scotter and Cody 1979; Douglas et al. 1981).

Polystichum braunii (Spenner) Fée — YUKON: This species was erroneously reported in *Flora North America* Volume 2, Pteridophytes and Gymnosperms (Wagner 1993) as occurring in the Yukon Territory, but Wagner (personal communication, 1995) stated that he had no knowledge of its occurrence in that area. It does, however, occur in the Alaska Panhandle.

Polystichum kruckebergii W.H. Wagner — YUKON: Wagner (1993) plotted a disjunct occurrence of this species in northern British Columbia and suggested (personal communication, 1995) that it might possibly also occur in southern Yukon Territory.

Polystichum munitum (Kaulfuss) C. Presl. —

YUKON: This species was erroneously reported in *Flora North America* Volume 2, Pteridophytes and Gymnosperms as occurring in the Yukon Territory but not mapped from that area by Wagner (1993). It was not reported from the Yukon Territory in his treatment of western *Polystichum* (Wagner 1979) and Wagner (personal communication 1995) stated that he had no knowledge of its occurrence there. Wagner (1979) and Cody and Britton (1989), however, do map a locality in northern British Columbia just south of the Yukon Territory border so it may occur in the Territory.

PINACEAE

Abies lasiocarpa (Hook.) Nutt., Alpine Fir — **YUKON:** shady *Picea* forest, Lower Beaver River, 60°02'03"N 124°31'40"W, *B. Bennett* 97-166, 9 June 1997 (DAO); La Biche River, 60°03'45"N 124°01'5"W, *B. Bennett* 95-200d, 6 June 1995 (DAO).

In southeastern Yukon, the nearest site mapped by Cody (1996) was a limestone ridge at 60°05'N 117°25'W. The location cited above is about 180 kilometers to the east. In western District of Mackenzie it occurs in the Mackenzie Mountains north to about 64°N.

Larix laricina (Du Roi) K. Koch, Tamarack — **YUKON:** La Biche River, 60°02'36"N 123°57'26"W, *B. Bennett* 95-240a, 15 June 1995 (DAO).

This species occurs in southeastern Yukon Territory and in the drainage of Peel and Porcupine rivers in the north (Cody 1996). The collection cited above is from an area about 180 kilometers east of the easternmost locality mapped by Cody (1996).

SPARGANIACEAE

Sparganium angustifolium Michx., Narrow-leaved Bur-reed — **YUKON:** Old Crow Flats, Enoch Lake, 68°06'15"N 140°11'W, *B. Bennett* 95-410, 10 Aug. 1995 (DAO).

The specimen cited above is an extension of the known range of this circumpolar species of about 375 kilometers north from a site in the Territory on the Dempster Highway.

Sparganium minimum (Hartm.) Fries, Small Bur-reed — **YUKON:** Upper Coal River, 61°12'N 127°16'W, *C. Zoladeski* 343-5-2, 22 July 1994 (DAO); Liard Plateau, 60°06'N 128°31'W, *G. Brunner* 178-2-3, 23 July 1994 (DAO).

This species was known to Douglas et al. (1981) from the vicinity of Dawson and considered rare in Yukon Territory. Cody (1994) reported additional sites at Big Salmon River, 61°53'N 134°55'W and Yukon River Basin, 62°08'N 133°00'W. The sites reported above extend the known range into the extreme southeast of the Territory.

Sparganium multipedunculatum (Morong.) Rydb., Bur-reed — **YUKON:** in muck in *Calamagrostis canadensis* meadow in drained beaver pond, Frances Lake area, 61°11'N 129°06'W, *R. Rosie* 1887, 12 Sept. 1995 (DAO).

The easternmost location plotted by Cody (1996) was approximately 132°10'W by the Campbell Highway. The location cited above is about 200 kilometers east southeast.

POTAMOGETONACEAE

Potamogeton alpinus Balbis ssp. *tenuifolius* (Raf.) Hultén, Pondweed — **YUKON:** roadside ditch, La Biche River area, 60°02'36"N 123°57'26"W, *B. Bennett* 95-242c, 15 June 1995 (DAO).

The location cited above is an eastward extension of the known range in southeastern Yukon about 200 kilometers from a site at 127°55'W on the Alaska Highway plotted by Cody (1996).

Potamogeton filiformis Pers. var. *borealis* (Raf.) St. John, Fine-leaved Pondweed — **YUKON:** ponds on roadside surrounded by *Picea mariana* bog, La Biche River, 60°02'36"N 123°57'26"W, *B. Bennett* 95-238a, 15 June 1995 (DAO); in very shallow water and on mud flats, Shaeffer Lake, Old Crow Flats, 68°05'44"N 140°15'44"W, *B. Bennett* 95-419, 11 Aug. 1995 (DAO); Old Crow Flats, Enoch Lake, 68°06'15"N 140°11'W, *B. Bennett* 95-412a, 10 Aug. 1995 (DAO).

The La Biche River site is an extension of the known range of about 180 kilometers eastward from a site plotted by Cody (1996); the Old Crow Flats sites are about 160 kilometers west northwest of the only location previously known in northern Yukon (Cody 1996).

Potamogeton gramineus L., Variable-leaved Pondweed — **YUKON:** Old Crow Flats, Shaeffer Lake, 68°05'44"N 140°02'44"W, *B. Bennett* 95-422, 11 Aug. 1995 (DAO); in 2 ft. water in beaver pond, La Biche River, 60°02'41"N 123°58'30"W, *B. Bennett* 95-244, 15 June 1995 (DAO).

Cody (1996) knew this pondweed as far north as just south of latitude 64°N in the Yukon Territory. The first specimen cited above is an extension of the known range of about 500 kilometers to the north. The second specimen is an extension of the known range 225 kilometers eastward into the southeastern region.

Potamogeton obtusifolius Mertens & Koch, Blunt-leaved Pondweed — **YUKON:** wetland, depth 20 cm, 60°39'N 136°40'W, *J. Majiski* 5023, 23 July 1984 (DAO) (determined by R. R. Haynes 1995).

This species, which is rare in the Yukon Territory, was known to Douglas et al. (1981) only from the Mount Sheldon area by the Canol Road. The specimen cited above, which was originally determined *P. friesii* Rupr., is the second record for the Territory.

Potamogeton strictifolius A. Bennett, Stiff-leaved Pondweed — YUKON: palustrine system characterized by Pond Lily and Water Arum, pond northeast of McQuesten Lake, 64°09'N 135°13'W, V. Loewen 22, 4 Aug. 1988 (DAO) (determined by R. R. Haynes 1995).

The specimen cited above (originally determined *P. friesii* Rupr.) is new to the flora of the Yukon Territory and should be added to the list of rare plants (Douglas et al. 1981). The two species can be separated as follows:

- A. Leaves obtuse or rounded and slightly mucronate, not conspicuously two-ranked; blades thin, 1.5-3.5 mm wide, flat, with 5-7 veins, with a narrow cellular-reticulate band along the midrib; winter buds fan-shaped; peduncles flattened *P. friesii*
- A. Leaves gradually tapered into a sharp bristle tip, conspicuously two-ranked; blades firm, 0.5-2.5 mm wide, convolute, with 3 (rarely 5) veins, without any cellular-reticulate band along the midrib; winter buds slender; peduncles teretew *P. strictifolius*

Erling Porsild (1951) reported *P. strictifolius* var. *rutiloides* Fern. new to the Yukon Territory based on a specimen from the Pelly River valley (Porsild 9874). This collection was mapped under that name by Porsild and Cody (1980). It has since been revised to *P. friesii* by R. R. Haynes.

Potamogeton zosteriformis Fern., Flat-stemmed Pondweed — YUKON: Shaeffer Lake, Old Crow Flats, 68°05'44"N 140°15'44"W, B. Bennett 95-422b, 11 Aug. 1995 (DAO).

Cody (1994) reported this species as new to the Yukon Flora on the basis of collections from 60°39'N 136°40'W and 64°04'N 135°23'W. The collection cited above extends the known distribution about 500 kilometers to the north-northwest.

SCHEUCHZERIAACEAE

Scheuchzeria palustris L. ssp. *americana* (Fern.) Hultén, Scheuchzeria — YUKON: in quaking bog on ridge-top, Frances Lake area, 61°12'N 129°06'W, R. Rosie 1886, 17 Sept. 1995 (DAO); Watson Lake, 60°05'N 128°49'W, G. Brunner 349-100-1, 19 July 1994 (DAO).

This is a rare plant in the Yukon Territory (Douglas et al. 1981). It was previously only known from the vicinities of Mayo and Pelly River, about 425 kilometers to the northwest.

ALISMATACEAE

Alisma plantago-aquatica L. var. *americana* J.A. Schultes (A. *triviale* Pursh), Water-plantain — YUKON: roadside ditch with *Typha*, La Biche River area, 60°04'4"N 124°02'57"W, 1150', B. Bennett 95-222, 14 June 1995; roadside ditch, La Biche River area, 60°02'36"N 123°57'26"W, 1225', B. Bennett 95-239a, 15 June 1995 (DAO).

Cody (1996) recently reported this species as new to the Northwest Territories north of 60°N latitude based on a collection from the Hanging Ice River,

60°34'N 112°13'W, about 500 km east of the collections cited above. To the west, although not known to Hultén (1968) it has been collected in Alaska in the Fairbanks Quad (Minto Flats and Goldstream Cr., 64°53'N 148°49'W, C.L. Parker 1695, 26 July 1985 (DAO)). This species is new to the Flora of the Yukon Territory and should be added to the list of rare plants (Douglas et al. 1981). To the south in British Columbia it is reported as common south of 52°N but rare northward (Douglas et al. 1994). The only other species of Alismataceae known in the Territory is *Sagittaria cuneata* Sheld. The two species may be distinguished as follows:

- A. Flowers all perfect; scape with whorled panicle branches and long-petioled, narrowly ovate to heart-shaped leaves *Alisma plantago-aquatica* var. *americana*
- A. Flowers monoecious, the lower pistillate, the upper and later developed staminate; leaf-blades commonly shaped like an arrowhead *Sagittaria cuneata*

POACEAE (GRAMINEAE)

Agrostis exarata Trin., Spike Bentgrass — YUKON: edge of warm spring, Frances Lake, 61°34'N 129°26'W, R. Rosie 1929, 18 July 1996 (DAO).

This species, rare in the Yukon Territory, was first known from mineral spring sites east of Watson lake (Scotter and Cody 1979). Cody (1994) extended the known range some 500 kilometers to the northwest in the McArthur/Ethel Lake area. The site reported above is situated between these two regions and is about 200 kilometers from the original areas.

Agrostis scabra Willd. var. *geminata* (Trin.) Swallen, Tickle Grass — YUKON: dry graminoid meadow with *Festuca altaica*, ca. 2 km SE of Gustly Lakes helicopter landing point, 60°24.49'N 126°25.59'W, Staniforth & Wilhelm, 16 Aug. 1995 (DAO).

Cody (1996) reported this variety of Tickle Grass in the Yukon Territory only in the southwest, west of 135°W longitude.

Alopecurus aequalis Sobol., Short-awned Foxtail — YUKON: riparian area, La Biche River, 60°04'41"N 124°02'57"W, B. Bennett 95-193c, 12 June 1995 (DAO).

The easternmost locality plotted by Cody (1996) was at the Irons Creek bridge, 60°00'N 127°52'W. The specimen cited above is an eastward extension of some 225 kilometers of the known range in the Yukon Territory. To the east, in the District of Mackenzie it is, however, known in the Liard River valley (Porsild and Cody 1980).

Beckmannia syzigachne (Steud.) Fern., Slough Grass — YUKON: moist mud on flat lakeside, Grassy Lake, Old Crow Flats, 68°11'40"N, 140°15'00"W, B. Bennett 95-434, 19 Aug. 1995 (DAO); wet ditch beside airstrip, La Biche Airstrip, 60°07'42"N 124°02'21"W, B. Bennett 97-208, 27 June 1997 (DAO).

This species is apparently rare north of latitude 66°N in the Yukon Territory. The first specimen cited above is the northernmost yet recorded and is an extension of the known range of about 100 kilometers northwest of the only previously known site near the Porcupine River (Cwynar 1983; Cody 1996). It was also observed at the village of Old Crow by Bennett; the second specimen cited is an extension of the known range in the southeast of about 200 kilometers.

Bromus carinatus Hook. & Arn. (*B. marginatus* Nees), California Brome — YUKON: shady riparian old *Picea glauca* forest, Tom Creek at Campbell Hwy., 60°14'25"N 128°59'12"W, *B. Bennett* 97-121, 8 July 1996 (DAO).

Hultén (1969) mapped the only other record of this species in the Yukon Territory in the vicinity of Carcross. It is a native western North American species which has been introduced northward.

Bromus inermis Leyss., Soft Chess — YUKON: roadside, La Biche River, 60°02'N 123°54'W, *B. Bennett* 95-220, 14 June 1995 (DAO).

The location cited above is an extension of the known range of this introduced species of about 220 kilometers from a site mapped by Cody (1996).

Bromus pumpellianus Scribn. var. *pumpellianus*, Smooth Brome — YUKON: moist meadow beside Coal River Springs, 60°08'N 127°25'W, *J. Staniforth* 10, Aug. 1995 (DAO); moist meadow below travertine formations at the springs, Coal River Springs, 60°08'N 127°25'W, *J. Staniforth* 13, Aug. 1995 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as the Canol Road. The specimens cited above are an extension of the known range eastward of about 350 kilometers. It is known further to the east however, in the Liard River valley in southwestern District of Mackenzie (Porsild and Cody 1980).

Calamagrostis canadensis (Michx.) Beauv. ssp. *canadensis*, Blue-joint — YUKON: growing on upturned root system of White Spruce blowdown, La Biche River, 60°02'59"N 123°59'26"W, *B. Bennett* 95-211, 14 June 1995 (DAO); La Biche River area, 60°33'N 124°12'W, *G. Brunner* 145-29-8, 6 Aug. 1994 (DAO).

The specimen cited above is an eastward extension of the known range of about 200 kilometers in the Territory (Cody 1996).

Calamagrostis lapponica (Wahlenb.) Hartm., Lapland Reedgrass — YUKON: Mount Merrill, 60°06'N 124°45'W, *G. Brunner* 211-12-1, 9 Aug. 1994 (DAO).

The specimen cited above extends the known range of this taxon in the Territory about 200 kilometers to the east.

Calamagrostis stricta (Timm) Koeler ssp. *inexpansa* (Gray) C.W. Greene, Slimstem Reedgrass — YUKON: sandy gravelly exposed flat, Beaver River-Larsen Creek area, 60°10'36"N 125°03'28"W, *B. Bennett* 95-283, 18 June 1995 (DAO).

The specimen cited above extends the known range of this taxon in the Territory about 150 kilometers to the east.

Cinna latifolia (Trev.) Griseb., Nodding Wood-reed — YUKON: shady riparian habitat, Beaver River-Larsen Creek area, 60°10'08"N 125°01'54"W, *B. Bennett* 95-297, 20 June 1995 (DAO); edge of warm spring, Frances Lake, 61°34'N 129°26'W, *R. Rosie* 1932, 18 July 1996 (DAO).

This species, rare in the Yukon Territory, was previously known only from the Coal River area, 60°09'N 127°26'W (Scotter and Cody 1979). The localities cited above lie about 175 kilometers to the east and 200 kilometers to the northwest of the Coal River site.

Danthonia intermedia Vasey, Timber Oat Grass — mesic graminoid meadow with *Festuca altaica*-*Rubus acaulis*, moss-lichen, 600 m ENE of helicopter landing point at Gusty Lake, 60°28.03'N 126°29.95'W, *C. Zoladeski*, 16 Aug. 1995 (DAO).

The easternmost collections of this species in the Yukon Territory known to Cody (1996) were along the Canol Road. The specimen cited above is an extension of the known distribution in the Territory about 375 kilometers to the east and southeast.

Elymus calderi Barkworth, Calder's Wild Rye — YUKON: old roadside, Liard River, 60°01'24"N 128°37'18"W, *B. Bennett* 97-125, 30 June 1996 (DAO); dry calcareous wash, Km 158 Dempster Hwy., *G. Brunner* 248, 28 June 1996 (DAO).

The specimen cited above, which was collected east of Watson Lake, is an eastward extension of the known range in the Yukon Territory of about 300 kilometers. It is, however, known in northern British Columbia near the Yukon border in the intervening area (Barkworth et al. 1996). The Dempster Highway collection is a northward extension of the known range of about 375 kilometers.

Elymus hispidus (Opiz) Meld. (*Agropyron intermedium* (Host) Beauv., *Elytrigia intermedia* (Host) Nevski), Intermediate Wheatgrass — YUKON: roadside, La Biche River, 60°02'49"N 123°59'00"W, *B. Bennett* 95-237, 15 June 1995 (DAO).

This species, which is introduced from Eurasia, has not previously been reported as occurring in the Yukon Territory. It is, as yet, apparently restricted to western North America: specimens in DAO are from Manitoba, Alberta, Wyoming, Utah and California. Douglas (1994) has recorded it as occurring in British Columbia. *Elymus hispidus* differs from *E. repens* in having the glumes not awned, their midveins usually equally prominent and scabrous

throughout or more prominent basally rather than shortly awned, their midveins more prominent and scabrous distally than proximally.

Festuca altaica Trin., Northern Rough Fescue — YUKON: mesic graminoid meadow, 600 m ENE of helicopter landing point at Gusty Lake, 60°28.03'N 126°29.95'W, C. Zoladeski, 16 Aug. 1995 (DAO); lichen/moss alpine tundra, La Biche Mountain Range, 60°33'19"N 124°29'12"W, Sharp & Cowell 3122, 6 Aug. 1994 (DAO); just below treeline on north side of main peak of Mt. Merrill, 60°08'15"N 124°41'52"W, Sharp et al. 3232, 9 Aug. 1994 (DAO).

The specimens cited above extend the known range of this species about 180 kilometers eastward in the Territory to near the District of Mackenzie border.

Festuca brachyphylla Schultes & Schultes fil., Alpine Fescue — YUKON: *Arctostaphylos alpina*/lichen alpine tundra, Mt. Skonseng ridge, 60°55.32'N 127°11.44'W, Zoladeski & Wilhelm, 17 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as the Canol Road. The specimen cited above is an extension of the known range of about 300 kilometers to the east.

Glyceria borealis (Nash) Batchelder, Northern Manna Grass — YUKON: along sandy/gravelly shore of lake, Frances Lake area, 61°11'N 129°14'W, R. Rosie 1877, 4 Aug. 1994 (DAO); Liard Plateau, 60°06'N 128°30'W, 810 m, G. Brunner 179-3-2, 23 July 1994 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). Cody (1996) reported it in the Territory from west of longitude 132°W. The specimens cited above extend the known range eastward in the Territory about 240 kilometers.

Glyceria grandis S. Wats., American Manna Grass — YUKON: *Carex-Calamagrostis* meadow, Frances Lake, 61°22'N 129°35'W, R. Rosie 1933, 14 Aug. 1996 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 134°11'W. The specimen cited above is an extension of the known range of about 300 kilometers to the east.

Hierochloë alpina (Sw.) R. & S., Alpine Holy Grass — YUKON: *Arctostaphylos alpina*/lichen alpine tundra, Mt. Skonseng ridge, 60°55.32'N 127°11.44'W, Zoladeski & Wilhelm, 17 Aug. 1995 (DAO); *Cassiope tetragona* alpine tundra, Mt. Skonseng ridge, 60°55.35'N 127°11.72'W, Wilhelm & Zoladeski, 17 Aug. 1995 (DAO); very open *Populus balsamifera* shrub thicket on youngest sandbar, downstream of Liard River at Upper Liard village, 60°02.54'N

128°54.03'W, Zoladeski and Kennedy, 23 Aug. 1995 (DAO); Quartz Creek, 60°21'N 127°56'W, C. Zoladeski 266-3-1, 23 July 1994 (DAO); lichen/moss alpine tundra at peak of mountain, La Biche Mountain Range, 60°33'19"N 124°29'12"W, Sharp & Cowell 3125, 6 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 129°W. The specimens cited above extend the known distribution about 275 kilometers to the east.

Leymus innovatus (Beal) Pilger (*Elymus innovatus* Beal), Fuzzy-spiked Wildrye — YUKON: La Biche River, 60°08'28"N 124°03'35"W, B. Bennett 95-147, 9 June 1995 (DAO).

The specimen cited above is an extension of the known range of this species in the Yukon Territory of about 190 kilometers eastward from a site mapped by Cody (1996).

Lolium perenne L. ssp. *perenne*, Perennial Rye Grass — YUKON: Watson Lake, G. Brunner 201, 17 July 1994 (DAO); reseeded new access road, approx. Km 96 Dempster Hwy., G. Brunner 296c, 7 Aug. 1996 (DAO).

This native of Europe is widely introduced and planted in North America. Although described and keyed in Cody (1996), the above collection represents the first documented report.

Lolium perenne L. ssp. *multiflorum* (Lam.) Husnot — YUKON: reseeded new access road, mixed with *Phleum pratense*, approx. Km 96 Dempster Hwy., G. Brunner 268, 7 Aug. 1996 (DAO).

Cody (1996) reported this introduced taxon only as far north as the vicinity of Dawson.

Oryzopsis asperifolia Michx., Rough-leaved Ricegrass — YUKON: roadside forest edge, La Biche River, 60°04'45"N 124°02'09"W, B. Bennett 95-204b, 13 June 1995 (DAO); dry south-facing slope, unnamed creek, 60°09'32"N 128°56'45"W, B. Bennett 97-85, 12 July 1996 (DAO).

This species, rare in the Yukon Territory, was first reported from the Coal River Springs area, 60°09'N 127°25'W (Scotter and Cody 1979) and was later collected in the same area east of Dan's Lake (C. Kennedy 60 (DAO)) in 1983. The specimens cited above, from an area about 230 kilometers to the east, and 55 kilometers to the west, are only the third and fourth collections from the Territory.

Oryzopsis pungens (Torr.) Hitchc., Mountain Rice — YUKON: sandy gravelly exposed flat, Beaver River-Larsen Creek area, 60°10'36"N 125°03'28"W, B. Bennett 95-283a, 18 June 1995 (DAO); wetland, Whitehorse area: N. Cousins Airstrip, 60°48'N 135°11'W, Kennedy et al. 67-101, 6 Sept. 1996 (DAO).

This rare species in the extreme south of the Yukon Territory was previously known only between

127°44.5'W and 129°35'W. The collections cited above are extensions of the known range about 150 kilometers to the east and 300 kilometers to the west.

Phalaris arundinacea L., Reed Canary Grass — YUKON: Old Crow Flats, 67°54'23.9"N 139°29'26.5"W, *J. Hawkings* 94029A, 1994 (DAO).

Cody (1994) reported this species which is rare in the Yukon Territory (Douglas et al. 1981) in the north of the Territory at Eagle Plains. The specimen cited above extends the known range about 225 kilometers further to the northwest.

Poa annua L., Annual Blue Grass — YUKON: on marsh side of path in disturbed *Alnus*-clay silt soil downslope, Beaver River-Larsen Creek area, 60°10'15"N 125°02'18"W, *B. Bennett* 95-298, 20 June 1995 (DAO); moist shaded spruce forest, same locality, *B. Bennett* 95-303, 21 June 1995 (DAO).

Cody (1996) reported this introduced species from only five widely distributed sites in the Yukon Territory. The known range is now extended about 150 kilometers eastward.

Poa arctica R. Br., Arctic Blue Grass — YUKON: *Arctostaphylos alpina*/lichen alpine meadow, Mt. Skonseng ridge, 60°55.32'N 127°11.44'W, *Zoladeski & Wilhelm*, 17 Aug. 1995 (DAO); *Vaccinium vitis-idaea*, *V. uliginosum*-*Salix reticulata*/moss-lichen ca. 30 kilometers N of camp ground on Nahanni Range Road, 61°41.69'N 128°17.62'W, *C. Zoladeski*, 11 Aug. 1995 (DAO); alpine lichen tundra W of Gusty Lakes, 60°21.41'N 126°33.05'W, *Zoladeski & Wilhelm*, 16 Aug. 1995 (DAO); *Salix* sp.-*Phyllodoce empetriformis*-*Festuca altaica*/moss dwarf shrub thicket, Thunder Mountain, 60°32.51'N 128°24.32'W, *C. Zoladeski*, 19 Aug. 1995 (DAO); dwarf shrub-rich meadow, Thunder Mountain, 60°32.51'N 128°24.09'W, *Kennedy & Wilhelm*, 19 Aug. 1995 (DAO); Quartz Creek, 60°21'N 127°57'W, *C. Zoladeski* 267-4-3, 23 July 1994 (DAO); La Biche River area, 60°33'N 124°33'W, *G. Brunner* 142-26-11, 6 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east in the Territory as longitude 129°W at latitude 62°N and about longitude 130°30'W in the extreme south. The specimens cited above, extend the known range east of the Campbell Highway and Nahanni Range Road 250 kilometers.

Poa arctica R.Br. ssp. *caespitans* (Simmons) Nannf., Arctic Blue Grass — YUKON: Lower Blow River Delta, 68°55'N 137°10'W, *Dickson & Allen* 5325, correction of latitude and longitude as published in Cody (1994) (L. Dickson, personal communication).

Poa glauca Vahl, Glaucous Bluegrass — YUKON: in open on side of river that floods yearly, La Biche River, 60°04'18"N 124°03'08"W, *B. Bennett* 95-180, 12 June 1995 (DAO); in Step Moss [*Hylocomium*

splendens] carpeted immature white and black spruce stand, Beaver River-Larsen Creek area, 60°10'01"N 125°01'23"W, *B. Bennett* 95-299, 20 June 1995 (DAO).

The collections cited above extend the known range in the Yukon Territory about 200 kilometers eastward.

Poa leptocoma Trin., Bog Bluegrass — YUKON: subalpine mixed meadow, Mt. Skonseng ridge, 60°55.55'N 127°11.47'W, *Staniforth & Wilhelm*, 17 Aug. 1995 (DAO); ca. 10 km N of Camp Ground on Nahanni Range Road, 61°23.40'N 128°22.31'W, *C. Zoladeski*, 12 Aug. 1955 (DAO).

Cody (1996) reported this species in the Yukon Territory as far southeast as the vicinity of Frances Lake. The specimens cited above extend the known range about 100 kilometers to the east.

Poa palustris L., Fowl-meadow Grass — YUKON: spruce bog, Beaver River-Larsen Creek area, 60°10'08"N 125°01'54"W, *B. Bennett* 95-294, 19 June 1995 (DAO); edge of beaver pond, La Biche River, 60°09'09'N 124°03'09"W, *B. Bennett* 95-261c, 16 June 1995 (DAO); slough, La Biche River, 60°04'43"N 124°02'14"W, *B. Bennett* 95-155a, 10 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only west of longitude 135°W. The specimens cited above extend the known range into the extreme southeast about 600 kilometers.

Poa porsildii Gjaerevol — YUKON: La Biche River area, 60°33'N 124°33'W, 1400 m, *G. Brunner* 142-26-12, 6 Aug. 1994; La Biche River area, 60°33'N 123°31'W, 1500 m, *R. Mueller* 157-52-2, 1500 m, 6 Aug. 1994.

Cody (1994, 1996) demonstrated that this species is much more common than it was known to Douglas et al. (1981). The specimen cited above however extends the known distribution southeast from the Macmillan Pass area (type locality) about 425 kilometers.

Poa pratensis L., Kentucky Blue Grass — YUKON: moist slope, La Biche River, 60°04'18"N 124°03'08"W, *B. Bennett* 95-187, 12 June 1995 (DAO); edge of moist beaver pond, La Biche River, 60°09'15"N 124°03'46"W, *B. Bennett* 95-175 (DAO); dry graminoid meadow with *Festuca altaica*, ca. 2 km SE of Gusty Lakes helicopter landing point, 60°24.49'N 126°25.59'W, *Staniforth & Wilhelm*, 16 Aug. 1995 (DAO).

The specimens cited above are an extension of the known range about 275 kilometers east from a site in the vicinity of Watson Lake mapped by Cody (1996).

Poa pratensis L. ssp. *alpigena* (Blytt) Hiit. — YUKON: La Biche River area, 60°32'N 124°30'W, *R. Mueller* 155-50-9, 6 Aug. 1994 (DAO).

The specimen cited above is an extension of the

known range about 180 kilometers eastward from a location about longitude 127°30'W mapped by Cody (1996).

Schizachne purpurascens (Torr.) Swallen, False Melic — YUKON: mesic graminoid meadow with *Festuca altaica*, 600 m ENE of helicopter landing point at Gusty Lakes, 60°28.03'N 126°29.95'W, *C. Zoladeski*, 16 Aug. 1995 (DAO); dry graminoid meadow with *Festuca altaica*, ca. 2 km SE of Gusty Lakes helicopter landing point, 60°24.49'N 126°25.59'W, *Staniforth & Wilhelm*, 16 Aug. 1995 (DAO); open *Populus balsamifera* on sandbars with *Salix-Alnus* understory, La Biche River, 60°09'18"N 124°03'55"W, *B. Bennett* 95-257, 16 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only from the Canol Road and the Coal River. The locations cited above are an extension of the known range about 200 kilometers eastward.

Trisetum spicatum (L.) Richt., Spike Trisetum — YUKON: subalpine mixed meadow, Mt. Skonseng ridge, 60°55.55'N 127°11.47'W, *Staniforth & Wilhelm*, 17 Aug. 1995 (DAO); dry graminoid meadow with *Festuca altaica*, ca. 2 km SE of Gusty Lakes helicopter landing point, 60°24.49'N 126°25.59'W, *Staniforth & Wilhelm*, 16 Aug. 1995 (DAO); sand and gravel bar over clay edge of river, La Biche River, 60°09'21"N 124°04'07"W, *B. Bennett* 95-263b, 16 June 1995 (DAO); rich alpine meadow in south-facing seepage area, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3156, 6 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 127°15'W. The sites reported above extend the known distribution about 200 kilometers eastward.

Vahlodea atropurpurea (Wahlenb.) Fries ssp. *latifolia* (Hook.) A.E. Porsild (*Deschampsia atropurpurea* (Wahlenb.) var. *latifolia* (Fries) Scribn.), Mountain Hairgrass — YUKON: Hyland River, 61°22'W 128°22'W, 1440 m, *G. Brunner* 124-36-2, 26 July 1994 (DAO).

Douglas et al. (1981) considered this species rare in the Yukon Territory on the basis of collections from Bennett Lake and the Canol Road. Cody (1994) extended the known range to the west to the McArthur/Ethel Lake area. The specimen cited above extends the known range southeast from the Canol Road locations about 225 kilometers.

CYPERACEAE

Carex aquatilis Wahlenb. ssp. *stans* (Drej.) Hultén, Water Sedge — YUKON: in lower areas on shallow sandy spit jutting into bay from beach ridge, southwest end of Stokes Point Lagoon, 69°21'N 138°44'W, *H.L. Dickson* 5905, 10 Aug. 1983 (DAO).

Cody (1996) stated "near the Arctic Coast occasional specimens approach what has been called *C. aquatilis* Wahlenb. ssp. *stans* (Drej.) Hultén (*C. stans* Drej.) of the high Arctic but are best treated as ssp. *aquatilis*." The specimens on the sheet cited above are a good match for specimens as far north as Ellesmere Island, although some of the second and third spikes do have stamens in the upper part, a feature which also occurs in the plants on the northern islands.

Carex aurea Nutt., Golden Sedge — YUKON: 10% moist slope, La Biche River, 60°04'18"N 124°03'08"W, *B. Bennett* 95-184c, 12 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°10'W. The specimen cited above extends the known range about 150 kilometers eastward.

Carex brunnescens (Pers.) Poir., Brownish Sedge — YUKON: La Biche River area, 60°33'N 124°32'W, *R. Mueller* 162-57-4, 8 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°30'W. The specimen cited above extends the known range about 175 kilometers eastward to near the District of Mackenzie border.

Carex buxbaumii Wahlenb., Buxbaum's Sedge — YUKON: in *Salix* thicket on flat near lakeshore, Frances Lake, 61°14'N 129°17'W, *R. Rosie* 1914, 15 Aug. 1996 (DAO).

This widespread circumpolar species is uncommon in the Yukon Territory north to about latitude 62°N. The specimen cited above is from about 160 kilometers northwest of the nearest known location at 60°07.5'N 127°21.5'W.

Carex canescens L., Grey Sedge — YUKON: marsh edge of alpine pond, near main peak of Mount Merrill, 60°07'47"N 124°41'11"W, *Sharp & Cowell* 3215, 9 Aug. 1994 (DAO); Toobally Lake, 60°12'N 126°19'W, *G. Brunner* 335-50-3, 14 July 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°30'W. The specimens cited above extend the known range about 175 kilometers eastward to near the District of Mackenzie border.

Carex concinna R. Br., Low Northern Sedge — YUKON: shaded willow thicket, riverbank, Lower Beaver River, 60°02'N 124°31'W, *B. Bennett* 97-176, 10 June 1997 (DAO); along bank of old channel of Larson Creek, 60°10'01"N 125°01'23"W, *B. Bennett* 95-296, 20 June 1995 (DAO); La Biche upriver bridge, 60°04'48"N 124°02'08"W, *B. Bennett* 95-000, 5 June 1995 (DAO); young *Populus balsamifera*, *Picea glauca* forest with *Alnus incana* understory, La Biche River, 60°09'03"N 124°03'48"W, *B. Bennett* 95-167, 12 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°15'W. The specimens cited above extend the known range about 190 kilometers eastward.

Carex consimilis Holm — YUKON: Mount Billings, 61°10'N 129°59'W, 1290 m, *Zoladeski & Mueller* 203-9-2, 9 July 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as longitude 133°W. The collection cited above extends the known distribution about 200 kilometers southeast from a site on the Canol Road.

Carex deweyana Schw., Dewey's Sedge — YUKON: slough bottom, La Biche River, 60°04'43"N 124°02'14"W, *B. Bennett* 95-155, 10 June 1995 (DAO); in established *Populus balsamifera* forests along La Biche woodland, La Biche River, 60°09'18"N 124°03'55"W, *B. Bennett* 95-259, 16 June 1995 (DAO).

This species, which is rare in the Yukon Territory (Douglas et al. 1981; Cody 1996) was previously only known in the Territory from Dawson.

Carex disperma Dewey, Soft-leaved Sedge — YUKON: Toobally Lake, 60°10'N 126°20'W, *G. Brunner* 337-62-3, 14 July 1994 (DAO); on marsh side of path in disturbed *Alnus*, Beaver River/Larsen Creek, 60°10'15"N 125°02'18"W, *B. Bennett* 95-298, 20 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as longitude 127°25'W. The specimens cited above extend the known range about 150 kilometers to the east.

Carex eleusinoides Turcz. — YUKON: wet meadow of *Eriophorum*, 10 kilometers N of campground on Nahanni Range Road, 61°23.33'N 128°23.32'W, *C. Zoladeski*, 13 Aug. 1995 (DAO).

The nearest collections of this species known to Cody (1996) were from the vicinity of Macmillan Pass on the Canol Road. The collection cited above is an extension of the known range about 200 kilometers to the southeast.

Carex foenea Willd., Silvertop Sedge — YUKON: bog, Beaver Ridge/Larsen Creek, 60°10'42"N 125°05'38"W, *B. Bennett* 95-314, 23 June 1995 (DAO).

Douglas et al. (1981) and Cody (1996) reported this rare species in the Yukon Territory only from the vicinities of Midway and Watson Lake. The specimen cited above is an extension of the known range of about 200 kilometers to the east.

Carex glareosa Wahlenb. — YUKON: Lower Blow River Delta, 68°56'N 137°09'W, *Dickson & Allen* 5303 — correction of latitude and longitude as published in Cody (1994) (L. Dickson, personal communication).

Carex interior Bailey, Inland Sedge — YUKON: wetland, Whitehorse area: north of Cousin's airstrip, 60°48'N 135°11'W, *Kennedy et al.* 67-7, 6 Sept. 1996 (DAO).

Cody (1996) reported this rare species in the Yukon Territory only between longitudes 127°07'W and 129°16'W, about 350 kilometers to the east.

Carex lachenalii Schk. — YUKON: Quartz Creek, 60°21'N 127°57'W, 1600 m, *C. Zoladeski* 265-1-6, 23 July 1994 (DAO); alpine mixed meadow, 10 kilometers N of campground on Nahanni Range Road, 61°22.78'N 128°22.72'W, *C. Zoladeski*, 13 Aug. 1995 (DAO); *Cassiope tetragona* alpine tundra, Mt. Skonseng, 60°55.35'N 127°11.72'W, *Wilhelm & Zoladeski*, 17 Aug. 1995 (DAO).

The specimens cited above extend the known range of this species in the Yukon Territory about 225 kilometers to the southeast from a site at approximately 62°N 129°W reported by Cody (1996).

Carex lapponica O.F. Lang (*C. canescens* L. var. *subuloliacea* Laest.) — YUKON: Upper Coal River, 60°12'N 127°17'W, 1030 m, *C. Zoladeski* 340-2-6, 22 July 1994 (DAO); Watson Lake, 60°05'N 128°49'W, 690 m, *G. Brunner* 352-103-3, 11 July 1994 (DAO); damp area, Watson Lake campground, *G. Brunner* 189, 16 July 1994 (DAO).

This species, which was considered rare in the Yukon Territory by Douglas et al. (1981), has not previously been reported from the area south and east of the Canol Road, a distance of about 325 kilometers (Cody 1996).

Carex lasiocarpa Ehrh. ssp. *americana* (Fern.) Hultén, Slender Sedge — YUKON: in *Salix/Carex* stand along shore of Wye Lake, Watson Lake area, 60°01'N 128°42'W, *R. Rosie* 1891, 25 Aug. 1995 (DAO); along edge of pond, Watson Lake, 60°06'N 128°49'W, *G. Brunner* 208, 17 July 1994 (DAO).

Douglas et al. (1981) knew this rare species in the Yukon Territory only from the Elsa area just south of latitude 64°N. Cody (1994) reported a second site from Eagle Lake west of Burwash Landing. The specimens cited above represent a third area in southeastern Yukon.

Carex lenticularis Michx. var. *lipocarpa* (Holm) L.A. Standley (*C. kelloggii* Boott), Kellogg's Sedge — YUKON: *Sphagnum* bog, SE of Watson Lake, 60°03'02"N 128°38'39"W, *B. Bennett* 97-128, 2 July 1996 (DAO).

Cody (1996) stated that Hultén (1968) indicated collection sites from just north of the British Columbia border in the Yukon Territory, but no substantiating specimens could be found and Douglas et al. (1981) stated that its presence in the Territory could not be confirmed. Although already described and keyed in Cody (1996) the specimen cited above does confirm its presence in the Territory and this

taxon should be added to list of rare vascular plants (Douglas et al. 1981).

Carex leptalea var. *tayloris* Boivin, Bristle-stalked Sedge — YUKON: La Biche River, 60°02'59"N 123°59'26"W, *B. Bennett* 95-216, 14 June 1995 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 250 kilometers to the east.

Carex limosa L., Shore Sedge — YUKON: Fantasque Lake, 60°15'N 124°53'W, *R. Mueller* 94-12-1, 7 Aug. 1994 (DAO).

The collection cited above is an extension of the known range of about 150 kilometers to the east and is the easternmost yet known in the Yukon Territory.

Carex loliacea L., Ryegrass Sedge — YUKON: boggy lake margin, unnamed lake, 60°03'N 127°36'W, *W.J. Cody* 32437, 8 July 1983 (DAO); roadside ditch, La Biche River, 60°01'19"N 123°51'56"W, *B. Bennett* 95-225a, 15 June 1995 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as near longitude 129°12'W. The specimens cited above extend the known range about 300 kilometers to the east.

Carex macloviana d'Urv., Falkland Island Sedge — YUKON: bog, Beaver River-Larsen Creek area, 60°10'42"N 125°05'38"W, *B. Bennett* 95-315, 23 June 1995; clay soil over sand, willow thicket-flat, La Biche River, 60°03'51"N 124°03'00"W, *B. Bennett* 95-178, 12 June 1995 (DAO); dry graminoid meadow with *Festuca altaica*, 2 kilometers SE of Gusty Lakes helicopter landing point, 60°24.49'N 126°25.59'W, *Staniforth & Wilhelm*, 16 Aug. 1995 (DAO); mesic graminoid meadow with *Festuca altaica* 600 m ENE of helicopter landing point at Gusty Lakes, 60°28.03'N 126°29.95'W, *C. Zoladeski*, 16 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as the Watson Lake area. The specimens cited above extend the known range about 275 kilometers eastward.

Carex macrochaeta C.A. Mey., Large-awned Sedge — YUKON: in moist meadow in cirque basin, Mount Haldane, approx. 63°52'N 136°46'W, *R. Rosie* 1819, 25 July 1986 (DAO).

Douglas et al. (1981) knew this rare species in the Yukon Territory only from southern Kluane National Park and the Carcross area. The specimen cited above extends the known range about 400 kilometers northward.

Carex magellanica Lam. ssp. *irrigua* (Wahlenb.) Hiit. — YUKON: *Carex* fen, between Beaver River and Fantasque Lake, 60°13'43"N 125°03'48"W, *Sharp & Cowell* 3180, 7 Aug. 1994 (DAO); Rock River, 60°43'N 127°32'W, *G. Brunner* 276-1-3, 22

July 1994 (DAO); Mount Laporte, 61°14'N 127°25'W, *G. Brunner* 208-25-1, 20 July 1994 (DAO); Nahanni Range Road, 61°19'N 128°16'W, *R. Mueller* 260-5-1, 26 July 1994 (DAO).

This species has not previously been recorded from the southeastern part of the Yukon Territory east of the Canol Road.

Carex marina Dewey — YUKON: Blow River Delta, 68°56'N 137°11'W, *Dickson & Allen* 5287 - correction of latitude and longitude as published in Cody (1994) (L. Dickson, personal communication).

Carex media R. Br., Scandnavian or Alpine Sedge — YUKON: La Biche River, 60°03'21"N 123°59'52"W, *B. Bennett* 95-243, 15 June 1995 (DAO); La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3138, 6 Aug. 1994 (DAO); Toobally Lake, 60°12'N 126°20'W, *G. Brunner* 333-58-6, 13 July 1994 (DAO).

Cody (1996) reported this species only west of longitude 128°W in the Yukon Territory. The specimens cited above extend the known range about 230 kilometers eastward.

Carex podocarpa R. Br. — YUKON: alpine lichen tundra, W of Gusty Lakes, 60°21.41'N 126°33.05'W, *Zoladeski & Wilhelm*, 16 Aug. 1995 (DAO); *Phyllodoce glanduliflora* alpine heath, Mt. Skonseng ridge, 60°55.35'N 127°11.79'W, *C. Zoladeski*, 17 Aug. 1995 (DAO); La Biche River area, 60°33'N 124°31'W, *R. Mueller* 158-53-16, 6 Aug. 1994 (DAO).

Cody (1996) reported this species from a site by the Nahanni Range Road at approximately 61°20'N latitude. The specimens cited above extend the known range in the Territory about 230 kilometers to the southeast.

Carex praticola Rydb., Meadow Sedge — YUKON: La Biche River, 60°06'34"N 124°05'39"W, *B. Bennett* 95-123b, 6 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 129°20'W. The specimen cited above is an extension of the known range about 300 kilometers to the east.

Carex pyrenaica Wahl. — YUKON: on alpine tundra slope west of Hyland River, 61°23'N 128°23'W, *R. Rosie* 1910, 1920, 1922, 25 July 1996 (DAO); tundra, Thunder Mtn. N slopes, 60°32.51'N 128°23.56'W, *C. Zoladeski*, 19 Aug. 1995 (DAO); *Phyllodoce glanduliflora* alpine heath, Mt. Skonseng, 60°55.35'N 127°11.79'W *C. Zoladeski*, 17 Aug. 1995 (DAO); alpine forb meadow, Nahanni Range Road, 61°23.4'N 128°22.31'W, *C. Zoladeski*, 12 Aug. 1995 (DAO).

The specimens cited above extend the known distribution in the Yukon Territory (Cody 1996) about 140 kilometers southeast from the vicinity of Frances Lake.

Carex rostrata Stokes — YUKON: Upper Coal River, 60°12'N 127°17'W, 1030 m, *C. Zoladeski* 340-2-8, 22 July 1994 (DAO); Upper Coal River, 60°12'N 127°17'W, 1030 m, *C. Zoladeski* 341-3-2, 22 July 1994 (DAO); Liard Plateau, 60°06'N 128°30'W, 810 m, *G. Brunner* 179-3-1, 23 July 1994 (DAO).

Cody (1994) reported this species from only two localities in the Yukon Territory and suggested that it should be added to the list of rare plants of the Territory (Douglas et al. 1981). Other specimens previously reported from the Territory have been revised to *C. utriculata*. The specimens cited above are situated between a site mapped by Cody (1996) east of Dawson and sites in Alberta (Griffiths 1989).

Carex saxatilis L., Russett Sedge — YUKON: marsh edge of alpine pond, near main peak of Mount Merrill, 60°07'47"N 124°41'11"W, *Sharp & Cowell* 3214, 9 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory as far east as about longitude 127°15'W. The specimen cited above extends the known range about 175 kilometers to the east.

Carex stylosa C.A. Mey., Long-styled Sedge — YUKON: bog, Beaver River/Larsen Creek, 60°10'42"N 125°05'38"W, *B. Bennett* 95-316, 20 June 1995 (DAO).

This is a rare species in the Yukon Territory where it was previously known only from the vicinity of Dawson and in the extreme southwest (Douglas et al. 1981; Cody 1996). The specimen cited above is an extension of the known range about 750 kilometers to the east.

Carex subspathacea Wormsk. — YUKON: Lower Blow River Delta, 68°56'N 137°09'W, *Dickson & Allen* 5301 — correction of latitude and longitude as published in Cody (1994) (L. Dickson, personal communication).

Carex utriculata Boott, Beaked or Bottle Sedge — YUKON: edge of lake, Grassy Lake, Old Crow Flats, 68°11'40"N 140°15'00"W, *B. Bennett* 95-437, 19 Aug. 1995 (DAO).

This species is frequent south of 64°N latitude and disjunct to the Porcupine River (Cody 1996). The specimen cited above is the northernmost yet reported in the Yukon Territory and extends the known range about 60 kilometers northward.

Carex vaginata Tausch — YUKON: bog, Beaver River/Larsen Creek, 60°10'42"N 125°05'38"W, *B. Bennett* 95-315, 23 June 1995 (DAO); edge of pond, La Biche River, 60°02'41"N 123°58'30"W, *B. Bennett* 95-245, 15 June 1995 (DAO); edge of beaver pond, La Biche River, 60°09'15"N 124°03'46"W, *B. Bennett* 95-196, 10 June 1995 (DAO); open *Picea glauca*/shrub-rich/feathermoss forest on slope, ca. 150 m S of helicopter landing

point at Gusty Lakes, 60°27.62'N 126°30.75'W, *Zoladeski et al.*, 16 Aug. 1995 (DAO); Toobally Lake, 60°12'N 126°20'W, *G. Brunner* 333-58-2, 13 July 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory as far southeast as the vicinity of Frances Lake. The specimens cited above extend the known range about 325 kilometers to the southeast.

Eleocharis acicularis (L.) R. & S., Needle Spike-rush — YUKON: growing on muddy lakeshore, Old Crow Flats, 68°05'13"N 140°09'53"W, *B. Bennett* 95-403, 9 Aug. 1995 (DAO).

This species is rare or overlooked north of latitude 64°N in the Yukon Territory. The specimen cited above is between one collected 5 kilometers south-east of King Point, 69°04'59"N 137°54'00"W and one from Mile 84 on the Dempster Highway.

Eleocharis palustris (L.) Roem. & Schult., Creeping Spike-rush — YUKON: in clay soil at edge of slough near Beaver River, 60°10'41"N 124°02'57"W, *B. Bennett* 95-310, 21 June 1995 (DAO); roadside ditch with *Typha*, La Biche River, 60°04'41"N 124°02'57"W, *B. Bennett* 95-221, 14 June 1995 (DAO); Enoch Lake, Old Crow Flats, 68°05'05"N 140°02'44"W, *B. Bennett* 95-416, 10 Aug. 1995 (DAO).

The specimens cited above extend the known range eastward about 200 kilometers in southeastern Yukon Territory and northward about 300 kilometers from a site on the Dempster Highway (Cody 1996).

Eriophorum angustifolium Honckn., Narrow-leaved Cotton-grass — YUKON: flat open low ground, La Biche River, 60°03'06"N 123°59'35"W, *B. Bennett* 95-234a, 15 June 1995 (DAO).

Cody (1996) reported this species in southeastern Yukon Territory only from the vicinity of Frances Lake. The specimen cited above extends the known range southeastward about 300 kilometers.

Eriophorum gracile Koch — YUKON: Upper Coal River, 61°12'N 127°16'W, *C. Zoladeski* 342-4-1, 22 July 1994 (DAO); in quaking bog, Frances Lake, 61°12'N 129°06'W, *R. Rosie* 1924, 23 June 1996 (DAO).

Cody (1994) reported this species new to the flora of the Yukon Territory on the basis of a specimen collected by C. E. Kennedy at the Coal River Springs 60°05'N 127°30'W (DAO). The collections cited above are from sites about 100 kilometers north and northwest of the Coal River Springs.

Eriophorum russeolum Fr. var. *albidum* Nyl. — YUKON: *Eriophorum* wet meadow, Thunder Mtn., 60°32.51'N 128°24.32'W, *Kennedy & Wilhelm*, 18 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory as far east as about longitude 131°W, near the upper Canol Road. The specimen cited above is

an extension of the known range of about 300 kilometers to the southeast.

Eriophorum vaginatum L., Sheathed Cotton-grass — YUKON: treed bog/bog complex halfway between the Beaver River and Fantasque Lake, 60°13'43"N 125°03'48"W, Sharp & Cowell 3177, 7 Aug. 1994 (DAO).

Cody (1996) reported this species which is common west of longitude 135°W in the Yukon Territory. The site reported above is an extension of the known range of about 575 kilometers to the east.

Eriophorum viridi-carinatum (Engelm.) Fern., Green-keeled Cotton-grass — YUKON: Hyland River, 61°22'N 128°17'W, G. Brunner 128-40-1, 27 July 1994 (DAO); wetland, Whitehorse area: north of Cousin's airstrip, 60°48'N 135°11'W, Kennedy et al. 67-3, 6 Sept. 1996 (DAO).

This species which was considered rare in the Yukon Territory by Douglas et al. (1981) was only known to Cody (1996) from four areas in the southeast of the Territory about 125 kilometers to the northeast.

Kobresia sibirica Turcz. (*K. hyperborea* A.E. Porsild) — YUKON: La Biche River area, 1500 m, 60°32'N 124°30'W, R. Mueller 155-50-12, 6 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only from occurrences west of longitude 136°W in the British, Richardson, Ogilvie and St. Elias mountains. To the east, however, it is known from Nahanni National Park in the southern Mackenzie Mountains in the District of Mackenzie (Scotter and Cody 1974).

Scirpus microcarpus Presl, Small-flowered Bulrush — YUKON: edge of moist beaver pond, La Biche River, 60°09'15"N 124°03'46"W, B. Bennett 95-169, 10 July 1995 (DAO).

Cody (1994) reported the first occurrence of this species in the Yukon Territory on the basis of a collection near the junction of the Stewart and Yukon rivers. The specimen cited above is the second recorded locality in the Territory.

ARACEAE

Calla palustris L., Wild Calla — YUKON: growing in 60 cm water in still marshy pond amongst *Carex*, La Biche River, 60°05'41"N 124°02'41"W, B. Bennett 95-266A, 17 June 1995 (DAO).

Cody (1996) considered the populations of this species in the west-central and northern Yukon Territory as apparently contiguous with the Alaskan population but separated from the main North American population by the Mackenzie Mountains. The La Biche locality cited above is about 750 kilometers southeast of sites in the vicinity of Mayo. In the District of Mackenzie nearby, it is known from Fisherman Lake at 60°22'N 123°46'W.

LEMNACEAE

Lemna minor L., Common Duckweed — YUKON: roadside ditch, La Biche River, 60°02'36"N 123°57'26"W, B. Bennett 95-242b, 15 June 1995 (DAO); Enoch Lake, Old Crow Flats, 68°05'05"N 140°09'50"W, B. Bennett 95-400a, 9 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory in the area west of longitude 135°W and north to latitude 64°N. The site at La Biche River is about 625 kilometers east of longitude 135°W, but the species is known from the Liard River valley in southwestern District of Mackenzie. The site at Enoch Lake is an extension of the known range of about 475 kilometers north from sites in the Dawson area.

Lemna trisulca L., Star Duckweed — YUKON: roadside ditch, La Biche River, 60°02'36"N 123°57'26"W, B. Bennett 95-242a, 15 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory as far east as longitude 127°21.5'W. The specimen cited above is an extension of the known range eastward of about 175 kilometers. To the east in the District of Mackenzie, the nearest known locality is in the vicinity of Fort Simpson (Porsild and Cody 1980).

JUNCACEAE

Juncus balticus Willd. var. *alaskanus* (Hultén) A.E. Porsild, Baltic Rush — YUKON: on marsh side of path in disturbed *Alnus*, Beaver River-Larsen Creek area, 60°10'15"N 125°02'18"W, B. Bennett 95-298, 20 June 1995 (DAO); silty mud in riparian area, La Biche River, 60°04'41"N 124°02'57"W, B. Bennett 95-192, 12 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°30'W. The specimens cited above extend the known range eastward about 200 kilometers.

Juncus castaneus Smith, Chestnut Rush — YUKON: dry old river channel, Beaver River-Larsen Creek area, 60°10'01"N 125°01'23"W, B. Bennett 95-289, 95-290a, 95-291, 19 June 1995 (DAO); 10% moist slope, La Biche River, 60°04'18"N 124°03'08"W, B. Bennett 95-184b, 12 June 1995 (DAO); *Eriophorum* wet meadow, Thunder Mtn. N slopes, 60°32.51'N 128°24.32'W, Kennedy & Wilhelm, 18 Aug. 1995 (DAO); alpine mixed meadow, 10 kilometers N of campground on Nahanni Range Road, 61°33.78'N 128°22.72'W, C. Zoladeski, 13 Aug. 1995 (DAO).

Cody (1996) reported this widespread species only as far east as longitude 129°W. The specimens cited above extend the known range eastward about 275 kilometers.

Juncus filiformis L., Thread Rush — YUKON: marsh edge of alpine pond, near peak of Mount

Merrill, 60°07'47"N 124°41'11"W, *Sharp & Cowell* 3217, 9 Aug. 1994 (DAO).

The site reported above is an extension of the known range in the Yukon Territory (Cody 1996) of about 225 kilometers eastward from approximately 128°W longitude.

Juncus stygius L. ssp. *americanus* (Buch.) Hultén, Bog Rush — YUKON: Upper Coal River, 61°12'N 127°16'W, *C. Zoladeski* 342-4-2, 22 July 1994 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981) and Cody (1996) where it was known only from the Mayo and Elsa areas. The collection cited above extends the known range about 550 kilometers to the southeast.

Luzula arcuata (Wahlenb.) Sw. ssp. *unalaschkensis* (Buch) Hultén, Curved Alpine Woodrush — YUKON: boulder field on north-facing slope, near main peak of Mt. Merrill, 60°08'03"N 124°41'30"W, *Sharp et al.* 3229, 9 Aug. 1994 (DAO).

The specimen cited above is an extension of the known range of about 200 kilometers southeast of a site west of longitude 127°W (Cody 1996).

Luzula confusa Lindeb., Confused Woodrush — YUKON: alpine lichen tundra, top of a small mountain ridge W of Gusty Lakes, 60°21.41'N 126°33.05'W, *Zoladeski & Wilhelm*, 16 Aug. 1995 (DAO); *Phyllodoce empetriformis* alpine tundra on Mt. Skonseng ridge, 60°55.35'N 127°11.79'W, *C. Zoladeski*, 17 Aug. 1995 (DAO); La Biche River area, 60°32'N 124°30'W, *R. Mueller* 155-50-11, 6 Aug. 1994 (DAO); lichen/moss alpine tundra at peak of mountain, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3126, 6 Aug. 1994 (DAO); *Betula glandulosa* /lichen alpine tundra, near main peak of Mt. Merrill, 60°07'47"N 124°41'11"W, *Sharp et al.* 3224, 9 Aug. 1994 (DAO).

The specimens cited above extend the known range of this species in eastern Yukon Territory (Cody 1996) about 200 kilometers to the southeast.

Luzula wahlenbergii Rupr., Wood Rush — YUKON: alpine forb meadow, ca. 10 kilometers N of campground on Nahanni Range Road, 61°23.40'N 128°22.31'N, *C. Zoladeski*, 12 Aug. 1995 (DAO); *Phyllodoce empetriformis* alpine heath, Mt. Skonseng, 60°55.35'N 127°11.79'W, *C. Zoladeski*, 17 Aug. 1995 (DAO); *Phyllodoce empetriformis* alpine heath tundra, Thunder Mtn. N slopes, 60°32.51'N 128°23.56'W, *C. Zoladeski*, 19 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only north of latitude 67°N. The specimens cited above extend the known range to the southeastern part. It is, however, known in the Mackenzie mountains in western District of Mackenzie (Porsild and Cody 1980).

LILACEAE

Maianthemum canadense Desf. ssp. *interius* (Fern.) A. & D. Löve, Wild Lily-of-the-Valley — YUKON: open shade in *Picea glauca* forest, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-276, 9 June 1997 (DAO); Beaver River, 60°12'N 125°09'W, *R. Mueller* 9-2-1, 5 Aug. 1994 (DAO); La Biche River, 60°03'48"N 124°01'51"W, *B. Bennett* 95-200e, 6 June 1995 (DAO); shaded *Picea glauca* / *Betula papyrifera* forest, Upper Gaswell, 60°07'25"N 124°06'02"W, *B. Bennett* 97-285, 26 June 1997 (DAO).

Cody (1994, 1996) suggested that this species should be looked for in extreme southeastern Yukon Territory because it was known from adjacent District of Mackenzie and British Columbia. The Mueller collection cited above consists of two sterile leaves only, but these are readily identifiable. The Bennett specimen has immature flowers. This taxon is new to the Yukon Territory and should be added to the list of rare species for that region (Douglas et al. 1981). It is described and keyed in Cody (1996).

Maianthemum trifolium (L.) Sloboda (*Smilacina trifolia* (L.) Desf.), Three-leaved Solomon's-seal — YUKON: Enoch Lake, 68°05'05"N 140°02'44"W, *B. Bennett* 95-404A, 9 Aug. 1955 (DAO).

The specimen cited above consists only of sterile leaves. Otherwise, this species is only known to occur in the Yukon Territory in the southeast. In the Mackenzie River valley to the east, however, it is known north to the Great Bear River area about latitude 65°N.

Streptopus amplexifolius (L.) DC. ssp. *americanus* (Schultes) A. & D. Löve — YUKON: Mount Merrill, 60°04'N 124°44'W, 1000 m, *R. Mueller* 227-22-4, 9 Aug. 1994 (DAO); open moist shaded *Picea glauca* forest, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-240, 10 June 1997 (DAO); *Abies lasiocarpa* forest, La Biche River, 60°07'39"N 124°06'16"W, *B. Bennett* 95-125, 6 June 1995 (DAO); on rotten mossy log, La Biche River, 60°08'N 124°03'37"W, *B. Bennett* 95-140, 8 June 1995 (DAO).

Cody (1996) stated that in the Yukon Territory this species occurs north to about latitude 63°N but is apparently rare. The specimens cited above extend the known range about 300 kilometers southeast from the vicinity of Frances Lake. It is, however, also present in nearby District of Mackenzie (Porsild and Cody 1980).

Tofieldia coccinea Richards., Northern False Asphodel — YUKON: Mount Merrill, 60°05'N 124°44'W, *R. Mueller* 225-20-1, 9 Aug. 1994 (DAO).

In the Yukon Territory Cody (1996) knew this species to be frequent north of latitude 64°N but rare south of latitude 62°N. The specimen cited above is an extension of the known range in the southeast of about 200 kilometers to the east.

ORCHIDACEAE

Amerorchis rotundifolia (Banks) Hultén (*Orchis rotundifolia* Banks), Round-leaved Orchis — YUKON: open spruce bog, Beaver River-Larsen Creek area, 60°10'20"N 125°02'19"W, *B. Bennett* 95-286, 19 June 1996 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as the vicinity of Watson Lake. The specimen cited above extends the known range about 200 kilometers to the east.

Corallorhiza trifida Chatelain, Coralroot — YUKON: uncommon in shaded open flat *Picea glauca*/*Betula papyrifera* forest, Lower Beaver River, 60°01'30"N 124°31'40"W, *B. Bennett* 97-201, 10 June 1997 (DAO); bank on side of moist side channel, La Biche River, 60°04'43"N 124°02'14"W, *B. Bennett* 95-150c, 10 June 1995 (DAO); edge of moist beaver pond, La Biche River, 60°09'15"N 124°03'46"W, *B. Bennett* 95-173b, 10 June 1995 (DAO).

Cody (1996) reported this orchid in the Yukon Territory only as far east as about longitude 127°10'W. The specimens cited above extend the known range about 180 kilometers to the east.

Cypripedium passerinum Richards., Sparrow's Egg Lady's-slipper — YUKON: Hyland River 61°10'N 128°18'W, *Rosie and Mueller* 111-1-94, 27 June 1994 (DAO); Hyland River, 61°29'N 128°14'W, *G. Brunner* 113-25-7, 25 July 1994 (DAO); Nahanni Range Road, 61°10'N 128°19'W, *R. Mueller* 256-14-3, 28 July 1994 (DAO).

The sites reported above are situated about 250 kilometers east of the easternmost sites known to Cody (1996) by the Canol Road.

Goodyera repens (L.) R. Br., Dwarf Rattlesnake-plantain — YUKON: Toobally Lake, 60°12'N 126°19'W, *Zoladeski & Mueller* 317-13-3, 13 July 1994 (DAO); La Biche River, 60°03'33"N 124°01'42"W, *B. Bennett* 95-130a, 7 June 1995 (DAO); mature *Populus balsamifera*, *Picea glauca* forest, La Biche River, 60°09'N 124°04'36"W, *B. Bennett* 95-260b, 16 June 1995 (DAO); *Abies lasiocarpa*/*Pinus contorta* forest on east-facing slope, southern extent of east arm of Mt. Merrill, 60°03'11"N 124°39'03"W, *Sharp et al.* 3236, 9 Aug. 1996 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as the Coal River Springs. The specimens cited above extend the known range about 190 kilometers to the east.

Listera cordata R. Br., Heart-leaved Twayblade — YUKON: flat open low ground, La Biche River, 60°03'06"N 123°59'35"W, *B. Bennett* 95-234b, 15 June 1995 (DAO); *Abies lasiocarpa*/*Pinus contorta* forest on east-facing slope, southern extent of east arm of Mt. Merrill, 60°03'11"N 124°34'03"W, *Sharp et al.* 3235, 9 Aug. 1994 (DAO); Mount Merrill,

60°06'N 124°45'W, *G. Brunner* 222-13-2, 9 Aug. 1994 (DAO).

Cody (1996) reported this orchid in the Yukon Territory only as far east as the vicinity of Watson Lake. The specimen cited above extends the known range about 290 kilometers to the east. In the District of Mackenzie it is known in the Mackenzie Mountains and Liard River valley (Porsild and Cody 1980).

Platanthera obtusata (Pursh) Lindl. (*Habenaria obtusata* (Pursh) Richards.) — YUKON: on mossy *Populus balsamifera* log, La Biche River, 60°03'45"N 124°01'51"W, *B. Bennett* 95-120, 6 June 1995 (DAO); on rotten *Populus balsamifera*, La Biche River, 60°03'33"N 124°01'42"W, *B. Bennett* 95-129c, 7 June 1995 (DAO); *Alnus crispa*/*Populus tremuloides* forest, La Biche Camp, 60°03'07"N 124°04'03"W, *B. Bennett* 97-323, 13 June 1997 (DAO).

This orchid is widespread in the Yukon Territory to north beyond latitude 68°N, but has not previously been reported east of longitude 127°W. The specimens cited above extend the known range eastward about 200 kilometers.

Platanthera orbiculata (Pursh) Lindl. (*Habenaria orbiculata* (Pursh) Torr.), Round-leaved Orchid — YUKON: near *Pinus contorta* with *Alnus crispa*/*Populus tremuloides* forest, moist, open, La Biche camp, 60°03'07"N 124°04'03"W, *B. Bennett* 97-322, 13 June 1997 (DAO); shaded *Picea glauca*/*P. mariana* forest in moss, Lower Beaver River, 60°01'30"N 124°31'40"W, *B. Bennett* 97-239, 10 June 1997 (DAO); Fantasque Lake, 60°15'N 124°53'W, 650 m, *R. Mueller* 97-15-1, 7 Aug. 1994 (DAO).

Cody (1996) described and keyed this species and suggested that it should be looked for in southeastern Yukon Territory. Szczawinski (1959), Luer (1975) and Porsild and Cody (1980) reported it from the Territory but no substantiating specimens could be located. It is known from the Liard Hot Springs in northeastern British Columbia (Porsild and Crum 1961) and from Flett Creek, a tributary of the Liard River (Jeffrey 1961) and Fort Liard region, 60°16'N 123°31'W, *G. Brunner* FTL-4-1, 4 Aug. 1994 (DAO), in southwestern District of Mackenzie. The occurrence in the Yukon Territory is now confirmed and it should be added to the list of rare plants of the region (Douglas et al. 1981).

SALICACEAE

Salix alaxensis (Anderss.) Cov. var. *alaxensis*, Alaska Willow — YUKON: riverside, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-248, 9 June 1997 (DAO); gravel bar of river, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-108c, 5 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only about as far east as longitude

129°15'W. The specimens cited above extend the known range eastward some 300 kilometers.

Salix arbusculoides Anderss., Northern Bush Willow — YUKON: *Picea glauca*/feathermoss forest, Rock River, 15 km N of Dalziel Creek, 60°43.24'N 127°12.29'W, G. Brunner, 22 July 1994 (DAO); *Larix laricina*-*Salix scouleriana*-*Alnus incana* woodland, Lower Toobally Lake, 60°10.54'N 126°20.10'W, G. Brunner, 14 July 1994 (DAO); riparian zone, La Biche River, 60°03'57"N 124°02'57"W, B. Bennett 95-191, 12 June 1995 (DAO); lakeside, Big Whitefish Lake, 68°11'50"N 140°15'10"W, B. Bennett 95-431, 19 Aug. 1995 (DAO).

Cody (1996) reported this willow in the Yukon Territory only as far east as about longitude 128°W. The specimens cited above extend the known range in the Territory about 230 kilometers to the east. The Big Whitefish Lake specimen is the northernmost yet found in the Territory.

Salix arctica Pall., Arctic Willow — YUKON: dwarf shrub thicket, Thunder Mountain, N slopes, cirque basin, 60°32.51'N 128°24.32'W, C. Zoladeski, 19 Aug. 1995 (DAO); *Phyllodoce empetrififormis* alpine heath tundra, Thunder Mountain, N slopes, on outer flank of cirque basin edge moraine, 60°32.51'N 128°23.56'W, C. Zoladeski, 19 Aug. 1995 (DAO); alpine, dwarf shrub-sedge-grass meadow, Quartz Creek, 60°20'N 127°57'W, C. Zoladeski, 23 July 1994 (DAO); *Cassiope tetragona*/lichen alpine heath, on east slopes of Mount Laporte, 61°13.63'N 127°26.06'W, G. Brunner, 20 July 1994 (DAO); *Betula glandulosa*/*Salix reticulata*/lichen/moss alpine tundra on north-facing slope near main peak of Mount Merrill, M.J. Sharp 3225, 9 Aug. 1994 (DAO).

Cody (1996) reported this willow which is found throughout most of the mountains of the Yukon Territory, only as far east as the Nahanni Range Road. The specimens cited above extend the known range into the extreme southeast.

Salix athabascensis Raup, Athabasca Willow — YUKON: in open *Picea mariana*/shrubs/moss stand, Frances Lake, 61°11'N 129°11'W, R. Rosie 1880, 7 June 1995 (DAO); low shrub in open *Picea mariana*, *Sphagnum* stand, Frances Lake area, 61°11'N 129°07'W, R. Rosie 1879, 7 June 1995 (DAO); *Carex* cf. *aquatilis* community, west arm of Frances Lake, Rosie & Mougeot, 20 June 1994 (DAO); *Betula glandulosa*/*Sphagnum* wetland, upper west arm of Frances Lake, G. Brunner, 24 June 1994 (DAO).

Cody (1996) reported this species in southern Yukon Territory where it apparently only occurred sporadically. The specimens cited above are from between locations along the Canol Road and Watson Lake.

Salix barclayi Anderss., Barclay's Willow — YUKON: La Biche River, 60°03'06"N 123°59'33"W, B. Bennett 95-234c, 15 June 1996 (DAO); *Abies lasiocarpa*/feathermoss forest, Liard Range, R. Mueller, 1994 (DAO); *Salix*/forb meadow, La Biche Mountain Range, 60°33'20"N 124°30'02"W, Sharp & Cowell 3208, 8 Aug. 1994 (DAO).

Cody (1996) mapped specimens of this species in the Yukon Territory north to about latitude 64°15'N and east to about longitude 127°15'W. The specimens cited above extend the known distribution eastward about 190 kilometers.

Salix brachycarpa Nutt. ssp. *brachycarpa*, Short-fruited Willow — YUKON: *Betula glandulosa*/willow/lichen south-facing alpine slope, La Biche Mountain Range, 60°33'19"N 124°29'12"W, Sharp & Cowell 3136, 6 Aug. 1994 (DAO).

This willow species, which was considered rare in the Yukon Territory by Douglas et al. (1981), was known to Cody (1996) in southern part of the Territory only as far east as the vicinity of Watson Lake. The specimen cited above is an extension of the known range in the Territory of about 250 kilometers to the east.

Salix commutata Bebb, Variable Willow — YUKON: subalpine *Salix*-dominated meadow, west slope of Mt. Billings, 61°10.94'N 128°59.99'W, Brunner & Steffen, 9 July 1994 (DAO); dwarf shrub thicket, ca. 10 km N of camp ground on Nahanni Range Road, 61°23.32'N 128°22.71'W, C. Zoladeski, 12 Aug. 1995 (DAO); along road near Hyland River, 61°26'N 128°16'W, R. Rosie 1943, 25 July 1996 (DAO); *Abies lasiocarpa* krummholz, Liard Range, 60°34'N 123°46'W, R. Mueller, 1994 (DAO).

Douglas et al. (1981) considered this willow rare in the Yukon Territory. Cody (1996) knew it only as far east in the Territory as about longitude 128°59'W. The specimens cited above extend the known range eastward some 275 kilometers.

Salix drummondiana Barratt, Drummond's Willow — YUKON: Beaver River, 60°11'N 125°09'W, G. Brunner, 10 Aug. 1994 (DAO); river edge in riparian zone, La Biche River, 60°03'51"N 124°03'00"W, B. Bennett 95-179, 12 June 1995 (DAO).

Douglas et al. (1981) considered this willow rare in the Yukon Territory. The collections cited above extend the known range eastward in the Territory about 200 kilometers from a site east of Watson Lake.

Salix exigua Nutt. ssp. *interior* (Rowlee) Cronq. (*S. interior* Rowlee var. *pedicellata* (Anderss.) Ball), Sandbar Willow — YUKON: riverside, Lower Beaver River, 60°02'N 124°31'40"W, B. Bennett 97-250, 9 June 1997 (DAO); gravel bar of river, La

Biche River 60°04'45"N 124°02'09"W, *B. Bennett* 95-108d, 5 June 1995 (DAO).

Cody (1996) mapped collections of this willow from three areas in the Yukon Territory: Porcupine River, Yukon River north of 63°N and in the vicinity of Watson Lake. The specimens cited above are from a fourth area about 280 kilometers east of Watson Lake.

Salix lanata L. ssp. *richardsonii* (Hook.) Skvortsov, Richardson's Willow — open *Picea glauca*/shrub-rich/feathermoss forest, on slope ca. 150 m S of helicopter landing point at Gusty Lakes, 60°27.62'N 126°30.75'W, *Zoladeski et al.*, 16 Aug. 1995.

Cody (1996) reported this willow as far east in the Yukon Territory as about longitude 129°10'W. The specimen cited above extends the known range about 175 kilometers to the east.

Salix maccalliana Rowlee, McCalla's Willow — YUKON: willow thicket, 7.3 km on Rancheria Road, 60°12'N 129°33'W, *G. Brunner*, 21 July 1994 (DAO).

Douglas et al. (1981) reported this rare species in the Yukon Territory on the basis of a specimen collected at Watson lake by G. Argus (CAN). Cody (1994) extended the known range to the east on the basis of a collection by C. Kennedy at the Coal River Springs. The specimen cited above from the third known locality is about 45 kilometers to the west of Watson Lake.

Salix myrtillofolia Anderss., Bilberry Willow — YUKON: *Pinus contorta* old burn, with *Betula glandulosa*, *Festuca altaica*/moss-lichen, ca. 2 km SE of Gusty Lakes helicopter landing point, 60°24.45'N 126°25.39'W, *C. Zoladeski*, 16 Aug. 1995 (DAO); spruce bog, Beaver River-Larsen Creek area, 60°10'20"N 125°02'19"W, *B. Bennett* 95-293a, 19 June 1995 (DAO); open black spruce bog, Beaver River-Larsen Creek area, 60°10'08"N 125°01'36"W, *B. Bennett* 95-285b, 19 June 1995 (DAO); black spruce bog, La Biche River, 60°03'13"N 123°59'59"W, *B. Bennett* 95-197a, 13 June 1995 (DAO).

Cody (1996) reported this willow only as far east in the Yukon Territory as about longitude 127°30'W. The specimens cited above extend the known range eastward about 225 kilometers.

Salix novae-angliae Anderss. — YUKON: dwarf *Salix-Phyllodoce glanduliflora-Vaccinium uliginosum* shrub thicket, ca. 10 kilometers N of campground on Nahanni Range Road, 61°23.32'N 128°22.71'W, *C. Zoladeski*, 12 Aug. 1995 (DAO).

Cody (1996) reported this species in eastern Yukon Territory in the vicinity of Watson Lake. The specimen cited above extends the known range in the eastern part of the Territory about 160 kilometers to the north.

Salix pedicellaris Pursh, Bog Willow — YUKON: low shrub fen dominated by *Chamaedaphne/Betula pumila/Larix*, between Beaver River and Fantásque Lake, 60°13'43"N 125°03'48"W, *Sharp & Cowell* 3182, 7 Aug. 1994 (DAO); in quaking bog on ridge-top, Frances Lake area, 61°12'N 129°06'W, *R. Rosie* 1884, 12 Sept. 1995 (DAO); same locality, *R. Rosie* 1945, 23 June 1996 (DAO); same locality, *R. Rosie* 1946, 25 Aug. 1996 (DAO).

This species which was considered rare in the Yukon Territory by Douglas et al. (1981) was previously known only from the vicinity of Watson Lake.

Salix polaris Wahlenb., Snow-bed Willow — YUKON: dwarf willow-*Luetkea pectinata*/moss, ca. 10 km N of campground on Nahanni Range Road, 61°23.40'N 128°22.31'W, *C. Zoladeski*, 12 Aug. 1995 (DAO); rich alpine meadow in south-facing seepage area, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3146, 6 Aug. 1994 (DAO); *Betula glandulosa/Salix reticulata*/lichen/moss alpine tundra on north-facing slope, near main peak of Mount Merrill, 60°08'03"N 124°41'30"W, *Sharp et al.* 3226, 9 Aug. 1994 (DAO).

Cody (1996) reported this species from the vicinity of Frances Lake. The specimens cited above extend the known range to the southeast about 325 kilometers.

Salix prolixa Anderss., Mackenzie's Willow — YUKON: flat wet ground, shady cottonwood forest, Beaver River-Larsen Creek area, 60°10'06"N 125°05'54"W, *B. Bennett* 95-284, 19 June 1995 (DAO).

This species, which is rare in the Yukon Territory (Douglas et al. 1981; Cody 1996), was previously known only from the vicinity of Watson Lake. The specimen cited above extends the known range about 225 kilometers to the east.

Salix pyrifolia Anderss., Balsam Willow — On hill-top, Tom Creek area N of Watson Lake, 60°16'N 128°59'W, *R. Rosie* 1355, 18 June 1981 (DAO); *Betula glandulosa* shoreline thicket, Watson Lake campground marsh, 60°05.54'N 128°49.12'W, *G. Brunner*, 19 July 1994 (DAO).

Cody (1996) mapped two localities in the Yukon Territory. The one from Palmer Lake on the west flank of the Richardson Mountains, 66°12'N 136°25'W (*Calder & Gillett* 26099 (DAO)) was the only one known to Douglas et al. (1981) for the Territory. The Tom Creek specimen cited above was the basis of the second site mapped by Cody but was not reported (Cody 1994). The collection by Brunner (above) is the third site known in the Territory.

Salix raupii Argus, Raup's Willow — YUKON: *Picea mariana-Larix laricina-Betula glandulosa-Ledum groenlandicum* open bog forest, east side of Tillei Lake, 61°45.52'N 129°28.34'W, *Mueller et*

al., 7 July 1994 (DAO); *Picea mariana*/*Sphagnum* woodland, Rock River, 15 km N of Dalziel Creek, 60°43.30'N 127°12.40'W, G. Brunner, 22 July 1994 (DAO).

Cody (1996) described and keyed this species, which is endemic to extreme western Alberta, north-eastern British Columbia and southwestern District of Mackenzie, and suggested that it should be looked for in southeastern Yukon Territory. The specimens cited above now confirm its occurrence in that area and it should be added to the list of rare plants (Douglas et al. 1981).

Salix reticulata L. ssp. *reticulata*, Net-veined Willow — YUKON: La Biche River, 60°33'N 124°32'W, G. Brunner, 1994 (DAO); La Biche River, 60°33'N 124°31'W, R. Mueller, 1994 (DAO).

This willow species is common throughout most of the Yukon Territory (Cody 1996). The specimen cited above however, is an extension of the known range of about 185 kilometers in the extreme southeast.

Salix scouleriana Barratt, Scouler's Willow — YUKON: young *Pinus contorta*-*Picea mariana*/feathermoss forest, NW end of Lower Toobally Lake, 60°14.20'N 126°20.25'W, Zoladeski et al., 12 July 1994 (DAO); *Populus tremuloides*/shrub rich forest, Lower Toobally Lake, 60°10.51'N 126°20.20'W, Zoladeski et al., 14 July 1994 (DAO); Mt. Merrill, 60°04'N 124°44'W, R. Mueller, 1994 (DAO); open *Populus tremuloides* forest *Alnus incana*, *A. crispa*, *Picea glauca* understory, La Biche Camp, 60°03'07"N 124°04'03"W, B. Bennett 97-325, 13 June 1997 (DAO).

The specimens cited above extend the known distribution of this willow in the Yukon Territory about 200 kilometers into the extreme southeast.

BETULACEAE

Betula glandulosa Michx., Ground Birch — YUKON: mature *Picea glauca*, *Populus balsamifera* forest-wet *Picea mariana* transition, La Biche River, 60°02'00"N 123°55'00"W, B. Bennett 95-232b, 15 June 1995 (DAO).

Cody (1996) reported this species, which is widespread in the Yukon Territory, only as far east as about longitude 127°20'W. The specimen cited above extends the known range eastward about 300 kilometers.

Betula neoalaskana Sarg., Alaska Paper Birch — YUKON: shady mature forest, La Biche River, 60°03'45"N 124°01'51"W, B. Bennett 95-116, 5 June 1995 (DAO); Old Crow Flats, Big Whitefish Lake, 68°11'08"N 140°15'49"W, B. Bennett 95-428B, 13 Aug. 1995 (DAO).

Cody (1996) reported this birch species in the Yukon Territory only as far east as about longitude 127°15'W. The specimen from La Biche River cited above extends the known range eastward about 200

kilometers, while the specimen from Big Whitefish Lake, although the species has previously been known from the Old Crow Flats, is the northernmost yet found in the Territory.

POLYGONACEAE

Oxyria digyna (L.) Hill, Mountain Sorrel — YUKON: Quartz Creek, 60°21'N 127°57'W, C. Zoladeski 265-1-3, 23 July 1994 (DAO); rich alpine meadow in south-facing seepage area, La Biche Mountain Range, 60°33'19"N 124°29'12"W, Sharp & Cowell 3150, 6 Aug. 1994 (DAO).

Cody (1996) reported this species which is frequent in much of the Yukon Territory, only as far east as about longitude 128°32'W. The specimens cited above extend the known range eastward about 250 kilometers.

Polygonum caurianum Robins. — YUKON: open grassy flat in front of cabin, Shaeffer Lake, Old Crow Flats, 68°05'N 140°02'44"W, B. Bennett 95-417B, 11 Aug. 1995 (DAO).

Douglas et al. (1981) considered this species rare in the Yukon Territory on the basis of specimens from Haines Junction, Mayo and Mount Sheldon. Cody (1994) extended the known distribution to the Canol Road, Stuart River, Dawson and Porcupine River areas. The specimen cited above is the northernmost yet found in the Territory, and extends the known distribution northward about 75 kilometers.

Rumex maritimus L. ssp. *fueginus* (Phil.) Hultén, Golden Dock — YUKON: Old Crow Flats, Enoch Lake, 68°06'15"N 140°11'W, B. Bennett 95-414a, 10 Aug. 1995 (DAO).

Cody (1996) reported this species only as far north as the vicinity of Dawson. The locality cited above is a northern extension of the known range in the Yukon Territory of about 400 kilometers.

CHENOPODIACEAE

Chenopodium capitatum (L.) Asch., Strawberry-blite — YUKON: upper part of clay mud slough with cobbles, La Biche River, 60°04'18"N 124°03'08"W, B. Bennett 95-183, 12 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°75'W. The specimen cited above extends the known range eastward about 230 kilometers.

PORTULACACEAE

Claytonia tuberosa Pall., Spring Beauty — YUKON: rich alpine meadow in south-facing seepage area, La Biche Mountain Range, 60°33'19"N 124°29'12"W, 4650 ft., Sharp & Cowell 3147, 6 Aug. 1994 (DAO); La Biche River area, 60°33'N 124°33'W, 1400 m, G. Brunner 142-26-14, 6 Aug. 1994 (DAO).

In southeastern Yukon Territory this species was previously known only from the Macmillan Pass area about 400 kilometers to the northwest (Cody

1996). It is, however, known in the southern Mackenzie Mountains in southwestern District of Mackenzie to the east.

CARYOPHYLLACEAE

Cerastium fontanum L. ssp. *triviale* (Link) Jalas, Common Mouse-ear Chickweed — YUKON: shady, moist, overgrown caterpillar trail, Beaver River-Larsen Creek area, 60°10'12"N 125°01'56"W, *B. Bennett* 95-277, 18 June 1995 (DAO); in marshy area under shady mature spruce, Beaver River-Larsen Creek area, 60°10'26"N 125°02'12"W, *B. Bennett* 95-280b, 18 June 1995 (DAO).

Cody (1996) reported this introduced species in the Yukon Territory only west of longitude 133°W.

Minuartia biflora (L.) Schinz. & Thell., Mountain Sandwort — YUKON: krummholz *Abies lasiocarpa*/Betula glandulosa/lichen south-facing alpine slope, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3140, 6 Aug. 1994 (DAO).

Cody (1996) reported this species only as far east in the Yukon Territory as about longitude 128°55'W near the District of Mackenzie border. The specimen cited above is from about 350 kilometers to the southeast.

Moehringia lateriflora (L.) Fenzl, Blunt-leaved Sandwort — YUKON: La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-113, 5 June 1995 (DAO); La Biche River, 60°08'59"N 124°03'37"W, *B. Bennett* 95-139c, 8 June 1995 (DAO); La Biche River, 60°08'28"N 124°03'20"W, *B. Bennett* 95-146a, 8 June 1995 (DAO); bank on side of moist side channel, La Biche River, 60°04'43"N 124°02'14"W, *B. Bennett* 95-150b, 10 June 1995 (DAO); Big Whitefish Lake, Old Crow Flats, 68°11'08"N 140°15'49"W, *B. Bennett* 95-426c, 13 Aug. 1995 (DAO).

Cody (1996) mapped this species in the Yukon Territory only as far east as about longitude 127°45'W. The La Biche River collections extend the known range in the Territory about 225 kilometers to the east. The Old Crow collection is a slight extension of the known range northward across 68°N latitude and is the northernmost yet reported in the Territory.

Silene noctiflora L., Night-flowering Catchfly — YUKON: growing with *Phleum pratense*, recently reseeded new access road to telecommunication tower, approx. Mile 35 Dempster Highway, *G. Brunner*, 31 July 1996 (DAO).

This introduced weedy species has not previously been found in the Yukon Territory. It is a viscid-vilous annual with stems up to 1 m high, lanceolate to ovate lanceolate leaves, few flowers in an open cyme, calyx cylindric with prominent green ribs, becoming inflated-ovate in fruit, and deeply cleft creamy-white petals.

Stellaria borealis Bigelow — YUKON: old river channel-sand over clay, Beaver River-Larsen Creek area, 60°10'01"N 125°01'23"W, *B. Bennett* 95-290, 19 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°20'W. The specimen cited above is an extension of the known range eastward about 200 kilometers.

Stellaria calycantha (Ledeb.) Bong., Northern Starwort — YUKON: mature *Populus balsamifera*, *Picea glauca* forest, La Biche River, 60°09'09"N 124°04'36"W, *B. Bennett* 95-260c, 16 June 1995 (DAO); in flowing water along roadside, La Biche River, 60°02'00"N 123°55'00"W, *B. Bennett* 95-229, 15 June 1995 (DAO); subalpine mixed meadow, Mt. Skonseng ridge, 60°55.55'N 127°11.47'W, *Staniforth & Wilhelm*, 17 Aug. 1995 (DAO).

Cody (1996) considered this species as rare in southern Yukon Territory. The specimens cited above extend the known range about 350 kilometers southeast of a site on the Yukon-Mackenzie border.

Stellaria longifolia Muhl., Long-leaved Chickweed — YUKON: Enoch Lake, Old Crow Flats, 68°05'05"N 140°09'50"W, *B. Bennett* 95-400b, 9 Aug. 1995 (DAO); sedge meadow with *Polemonium acutiflorum*, *Geum macrophyllum*, 2 km E of Fantasque Lake, 60°14'19"N 124°49'55"W, *Sharp & Cowell* 3165, 7 Aug. 1994 (DAO); upland grass/forb meadow in valley of La Biche River, 60°31'12"N 124°43'58"W, *Sharp & Cowell* 3183, 8 Aug. 1994 (DAO).

The first collection cited above is the northernmost collection of this species in the Yukon Territory; Cody (1996) did, however, map a collection by L. C. Cwynar from Shaeffer Clearing at the junction of Shaeffer Creek and Old Crow River, 67°50'N 139°51'W (DAO). The two collections from the southeast of the Territory are an extension of the known range eastward of about 250 kilometers from the vicinity of Watson Lake.

RANUNCULACEAE

Actaea rubra (Ait.) Willd. ssp. *arguta* (Nutt.) Hultén, Red Baneberry — YUKON: forest edge, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-111, 5 June 1995 (DAO).

Cody (1996) reported this subspecies in the Yukon Territory only as far east as longitude 131°W. The specimen cited above extends the known range eastward about 400 kilometers.

Aquilegia brevistyla Hook., Small-flowered Columbine — YUKON: roadside with *Picea* and *Betula papyrifera*, La Biche River, 60°03'00"N 124°03'14"W, *B. Bennett* 95-134, 8 June 1995 (DAO); meadow by roadside to Upper Gaswell, 60°07'25"N 124°06'02"W, *B. Bennett* 97-195, 16 June 1997 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°15'W. The specimens cited above extend the known range about 175 kilometers to the east.

Caltha natans Pall., Floating Marsh-marigold — YUKON: growing in shallow water on silty mud, Grassy Lake, Old Crow Flats, 68°11'40"N 140°15'49"W, *B. Bennett* 95-433, 19 Aug. 1995 (DAO).

The specimen cited above is the northernmost yet recorded in the Yukon Territory. The only other collection known to Cody (1996) from north of 66° latitude in the Territory was found by J. V. Matthews at Netro Lake, 67°50.76'N 139°7.10'W on 23 July 1981 (DAO), about 60 kilometers to the southeast.

Pulsatilla ludoviciana (Nutt.) Heller (*Anemone patens* L. var. *multifida* Pritzel), Prairie-crocus — YUKON: Watson Lake, 60°09'N 129°06'W, 750 m, *G. Brunner* 361-7-1, 22 June 1994 (DAO).

Cody (1996) reported this species in southeastern Yukon Territory only from sites by the Canol Road about 250 kilometers to the west of the Watson Lake locality cited above.

Ranunculus eschscholtzii Schlecht. — La Biche River area, 60°33'N 124°32'W, *G. Brunner* 144-28-6, 6 Aug. 1994 (DAO); *Salix*/forb meadow, La Biche Mountain Range, 60°33'20"N 124°30'02"W, *Sharp & Cowell* 3206, 8 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°15'W. The collections cited above extend the known range about 200 kilometers to the southeast.

Ranunculus gmelinii DC. ssp. *purshii* (Richards.) Hultén — YUKON: roadside pond, La Biche River, 60°01'19"N 123°51'56"W, *B. Bennett* 95-226, 15 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as longitude 129°W. The specimen cited above is an extension of the known range of about 300 kilometers eastward.

Ranunculus hyperboreus Rottb., Arctic Buttercup — YUKON: emergent on clay flats of Beaver Pond, La Biche River, approx. 60°05'41"N 124°02'12"W, *B. Bennett* 95-267, 17 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as the vicinity of Frances Lake. The specimen cited above is an extension of the known range about 325 kilometers to the southeast.

Ranunculus lapponicus L., Lapland Buttercup — YUKON: Toobally Lake, 60°12'N 126°19'W, *G. Brunner* 335-60-1, 14 July 1994 (DAO); black spruce bog, La Biche River, 60°03'13"N 123°59'57"W, *B. Bennett* 95-195a, 13 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 128°30'W. The specimens cited above extend the known range about 260 kilometers to the east.

Ranunculus macounii Britt., Macoun's Buttercup — YUKON: muddy banks of slough on clay soil, Beaver River-Larsen Creek area, 60°10'40"N 128°08'11"W, *B. Bennett* 95-307, 21 June 1995 (DAO); muddy silty ground near beaver pond, La Biche River, 60°04'41"N 124°02'42"W, *B. Bennett* 95-157, 10 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°20'W. The specimens cited above extend the known range in the Territory about 200 kilometers to the east.

Ranunculus sceleratus L. ssp. *multifidus* (Nutt.) Hultén, Celery-leaved Buttercup — YUKON: La Biche River, 60°04'18"N 124°03'W, *B. Bennett* 95-186b, 12 June 1995 (DAO); La Biche River, 60°04'41"N 124°02'57"W, *B. Bennett* 95-193a, 12 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°20'W. The specimens cited above extend the known range about 200 kilometers to the east.

PAPAVERACEAE

Papaver alboroseum Hultén, Pale Poppy — YUKON: mountain ridge; Kluane National Park, near headwaters of Dalton Creek, 5700 ft., 60°22'N 137°22'W, *M. J. Whitley*, 2 Sept. 1985 (DAO).

This species, which has not previously been reported from the Yukon Territory, is an extension of the known range eastward from the Sheep Glacier, 60°42'N 141°39'W in Alaska (Murray 1971); it is also known in northwestern British Columbia (Douglas et al. 1990). It should be added to the list of rare plants (Douglas et al. 1981). It is a caespitose plant with scapes to 15 cm high, with a short caudex clothed with brownish leaf bases; leaves 2–8 cm long, twice pinnatifid, pubescent with curved, coarse whitish to pinkish spreading hairs; sepals blackish to brownish; petals white to pink, often with a basal yellowish spot, 12–20 mm long; capsules ovate to globose, 10–15 mm long, with white to brown, stiff setae; stigma with 5–6 rays.

BRASSICACEAE (CRUCIFERAE)

Alyssum americanum Greene, American Alyssum — YUKON: Mayo District, McArthur Mt., 4200 ft., at the Hot Springs, *H. Bostock* 169, 18 June 1940 (CAN).

Cody (1996) inadvertently mapped the collection cited above at 60°36'N 140°14'W in the Kluane park area. In rechecking the specimen, Mayo District has been noted on the label. This would place the locality in the McArthur Group of mountains, a part

of the McArthur Game Sanctuary, approximately 63°00'–63°15'N 135°15'–136°00'W.

Arabis calderi Mulligan — YUKON: occasional in openings in dwarf birch-willow thickets on flats at 2600 ft., Mile 25 from Alaska Highway on road to Dawson, 61°08'N 135°20'W, *Calder & Gillett* 25788, 22 June 1960 (DAO, ALA); alpine meadows near a mountain stream, Mt. Caribou, alt. 6469 ft., 5 miles north of Carcross, 60°14'N 134°42'W, *Gillett & Mitchell* 4545, 17 August 1949 (DAO); in slightly saline grassy clearing between spruce-Aspen groves, Champagne at Mile 974 Alaska Highway, 60°47'N 136°29'W, *Calder & Gillett* 25142, 8 June 1960 (DAO); prairie, vicinity of Pine Creek, Alaska Highway, approx. 60°47'N 137°35'W, *Raup et al.* 13033, 2 June 1948 (ALA, photo DAO); rangeland occupied by both elk and horses which straddles the Alaska Highway at the Takhihi River burn (1958), Stony Creek, 60°50'N 135°50'W, *R. Florkiewicz* 76, 2 May 1988 (DAO); sandy land and silty loam, Mile 135 Haines Road, *J. W. Abbott* 11, 26 May 1946 (DAO).

The type of this new species which was described by G. A. Mulligan (1995) was collected at Indian River in northeastern British Columbia. Elsewhere in Canada it is known from Great Bear Lake in the Northwest Territories, southwestern Alberta, and British Columbia. It should be added to the list of rare species in the Yukon Territory (Douglas et al. 1981).

Arabis codyi Mulligan — YUKON: unstable slopes, Kaskawulsh nunatak, jct. N and central arms Kaskawulsh Glacier, W of Kluane Lake, 6000 ft., *D. F. & D. M. Murray* 72, 1 July–1 August 1965 (DAO).

The specimen cited above is the holotype of a new species which was described by G. A. Mulligan (1995). Elsewhere it is only known from Perew, British Columbia, 54°30'N 126°26'W. It should be added to the list of rare species in the Yukon Territory (Douglas et al. 1981).

Arabis divaricarpa A. Nels. var. *divaricarpa*, Spreading-pod Rockcress — YUKON: La Biche River, 60°04'22"N 124°03'09"W, *B. Bennett* 95-166, 12 June 1995 (DAO).

Cody (1996) reported this species as far east in the Yukon Territory as about 127°15'W. The specimen cited above is an extension of the known range of about 200 kilometers to the east.

Arabis kamtchatika Ledeb. — YUKON: riverbar, Lower Beaver River, 60°02'N 124°31'W, *B. Bennett* 97-252, 9 June 1997 (DAO); wet areas beside beaver pond, La Biche River, 60°04'41"N 124°02'42"W, *B. Bennett* 95-163, 10 June 1995 (DAO).

Cody (1996) reported this species in southeastern Yukon Territory from west of Watson Lake and the

upper Hyland River. The specimens cited above are an extension of the known range to the east and southeast of about 275 kilometers.

Arabis murrayi Mulligan — YUKON: Kaskawulsh nunatak, jct. N and central arms Kaskawulsh Glacier, W of Kluane Lake, 6000 ft., *D. F. & D. M. Murray* 91b, 1 July–1 August 1965 (Holotype DAO, Isotypes ALA, CAN).

Elsewhere in Canada this species which was described by G. A. Mulligan (1995) is known from alpine slopes in southwestern Alberta and southern British Columbia and in the United States in Washington and western Montana. It should be added to the list of rare species in the Yukon Territory (Douglas et al. 1981).

Barbarea orthoceras Ledeb., American Winter Cress — YUKON: 10% moist slope, La Biche River, 60°04'18"N 124°03'08"W, *B. Bennett* 95-185, 12 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as the vicinity of Watson Lake. The specimen cited above is an extension of the known range of about 275 kilometers to the east.

Brassica rapa L., Bird Rape — YUKON: reseeded new access road., approx. Km 96 Dempster Hwy., *G. Brunner* 269a, 7 Aug. 1996 (DAO).

This cosmopolitan introduced species was previously known in the Yukon Territory from two localities: east of Dempster Hwy Km 8 and Haines Road, near Dezadeash Lake (Cody 1994).

Cardamine bellidifolia L., Alpine Bitter-cress — YUKON: Hyland River, 61°22'N 128°21'W, *G. Brunner* 119-31-2, 26 July 1994 (DAO); lichen/moss tundra at peak of mountain, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3119, 6 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 128°33'W. The specimens cited above extend the known range about 325 kilometers to the southeast.

Cardamine pensylvanica Muhl., Pennsylvanian Bitter-cress — YUKON: river bar, sand and gravel over clay, Beaver River-Larsen Creek area, 60°10'06"N 125°01'57"W, *B. Bennett* 95-271B, 18 June 1995 (DAO); Beaver River-Larsen Creek area, 60°10'26"N 125°02'12"W, 18 June 1995 (DAO); in ditch with *Chrysosplenium tetrandrum*, La Biche River, 60°08'28"N 124°03'20"W, *B. Bennett* 95-143, 8 June 1995 (DAO); clay soil at edge of beaver pond, La Biche River, 60°08'59"N 124°03'37"W, *B. Bennett* 95-250a, 10 June 1995 (DAO).

Cody (1996) reported this species in southeastern Yukon Territory only between the Canol Road and about longitude 127°15'W. The specimens cited above extend the known range about 200 kilometers to the east.

Cardamine pratensis L., Cuckoo Bitter-cress — YUKON: submerged in flooded beaver pond, La Biche River, 60°08'59"N 124°03'37"W, *B. Bennett* 95-139a, 8 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°15'W. The specimen cited above extends the known range about 200 kilometers to the east.

Draba borealis DC., Northern Whitlow-grass — YUKON: Mount Billings, 61°10'N 128°59'W, *Zoladeski & Mueller* 202-8-2, 9 July 1994 (DAO); subalpine mixed meadow, Mt. Skonseng ridge, 60°55.55'N 127°11.47'W, *Staniforth & Wilhelm*, 17 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 129°25'W. The specimens cited above extend the known range about 130 kilometers to the east.

Draba cana Rydb., Lance-leaved Draba — YUKON: on tundra on Mount Billings, Frances Lake area, 61°14'N 128°53'W, *R. Rosie* 1874, 7 July 1994 (DAO).

Cody (1996) mapped specimens in southeastern Yukon Territory from Coal River Springs, 60°09'N 127°26'W, a limestone ridge at 60°05'N 127°25'W and sites adjacent to the Canol Road. The locality cited above is situated between these two areas.

Draba fladnizensis Wulfen, Whitlow-grass — YUKON: La Biche River area, 60°33'N 124°31'W, 1440 m, *R. Mueller* 160-55-9, 8 Aug. 1994 (DAO).

In southeastern Yukon Territory the nearest sites mapped by Cody (1996) are by the Canol Road near Ross River, about 450 kilometers to the northwest. This species occurs however, in the southern Mackenzie Mountains in southwestern District of Mackenzie.

Draba longipes Raup, Long-stalked Whitlow-grass — YUKON: La Biche River area, 60°33'N 124°33'W, *G. Brunner* 142-26-7, 6 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 129°W. The specimen cited above extends the known range about 350 kilometers to the southeast.

Eutrema edwardsii R.Br., Edward's Wallflower — YUKON: La Biche River area, 60°32'N 124°30'W, *R. Mueller* 155-50-3, 6 Aug. 1994 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 300 kilometers southeast of the vicinity of Frances Lake.

Lepidium bourgeauanum Thell., Bourgeau's Pepper-grass — YUKON: riparian zone, La Biche River, 60°03'13"N 123°59'59"W, *B. Bennett* 95-194, 13 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude

127°20'W. The specimen cited above extends the known range about 200 kilometers to the east.

Rorippa curvipes E.L. Greene var. *truncata* (Jepson) Rollins — YUKON: on packed gravelly disturbed ground, Ross River-Faro area, 62°18'N 133°21'W, *R. Rosie* 1082B, 24 July 1982 (DAO).

This specimen was determined *R. palustris* (L.) Besser ssp. *palustris* and mapped as that by Cody (1996). It was recently revised by G. A. Mulligan to *R. curvipes truncata*, a taxon which is new to the Yukon Territory. This entity occurs in Canada from southern British Columbia east to Saskatchewan south in the United States to Texas, California and New Mexico. It may be introduced in the Yukon Territory and was growing near to *R. palustris* (*R. Rosie* 1082A). It may be distinguished from *R. palustris* by its shorter fruiting pedicels (2 to 4 mm long and shorter than siliques, rather than 4 to 12 mm long, and longer than siliques) and with stems often spreading or decumbent, to 40 cm high rather than usually erect, and 30 to 100 cm high.

Thlaspi arvense L., Penny Cress — YUKON: flower bed, Whitehorse, 60°36'N 134°58'W, *N. Hughes*, 13 Aug. 1995 (DAO); Watson Lake Airport, 60°05'18"N 129°45'50"W, *B. Bennett* 97-355, 7 June 1997 (DAO).

This introduced weedy species is known from occasional localities in the Yukon Territory as far north as Dawson (Cody 1996) but has not previously been recorded from the Whitehorse or Watson Lake areas.

DROSERACEAE

Drosera anglica Huds., Great Sundew — YUKON: Fantasque Lake, 60°15'N 124°53'W, *R. Mueller* 94-12-2, 7 Aug. 1994 (DAO).

The above specimen is an eastward extension of about 150 kilometers of the known range of a species which was considered rare in the Yukon Territory by Douglas et al. (1981).

SAXIFRAGACEAE

Parnassia kotzebuei Cham. & Schlecht., Grass-of-Parnassus — YUKON: in silty clay in old stream channel of Larsen Creek, 60°10'01"N 125°01'23"W, *B. Bennett* 95-299, 20 June 1995 (DAO); dry exposed area by pond, La Biche River, 60°02'36"N 123°57'26"W, *B. Bennett* 95-241b, 15 June 1995 (DAO); La Biche River area, 60°33'N 124°31'W, *R. Mueller* 158-53-3, 6 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory as far east as about longitude 127°15'W. The specimens cited above extend the known range about 200 kilometers to the east.

Ribes glandulosum Grauer, Skunk Currant — YUKON: throughout *Picea glauca* mixed forest, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-159, 10 June 1997 (DAO); shady forest

edges, La Biche River, 60°04'45"N 124°02'28"W, *B. Bennett 95-189b*, 12 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory as far east as about longitude 127°10'W. The specimens cited above extend the known range about 200 kilometers to the east.

Ribes hudsonianum Richards., Northern Black Currant — YUKON: bog, La Biche River, 60°03'13"N 123°59'59"W, *B. Bennett 95-198*, 13 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°30'W. The specimen cited above extends the known range about 215 kilometers to the east.

Ribes lacustre (Pers.) Poir., Bristly Black Currant — YUKON: Toobally lake, 60°12'N 126°20'W, *G. Brunner 334-59-1*, 13 July 1994 (DAO); shady, old *Picea glauca*/*Betula papyrifera* forest, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett 97-259*, 9 June 1997 (DAO); La Biche River, 60°03'45"N 124°01'51"W, *B. Bennett 95-117a*, 5 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°15'W. The specimens cited above extend the known range about 190 kilometers to the east.

Saxifraga caespitosa L., Tufted Saxifrage — YUKON: La Biche River area, 60°33'N 124°33'W, *G. Brunner 142-26-1*, 6 Aug. 1994 (DAO).

The site reported above lies about 350 kilometers east of the nearest known locality in southern Yukon Territory. It is, however, known in the Mackenzie Mountains to the east, in western District of Mackenzie (Porsild and Cody 1980).

Saxifraga flagellaris Willd. ssp. *setigera* (Pursh) Tolm., Spiderplant — YUKON: La Biche River area, 60°33'N 124°33'W, 1400 m, *G. Brunner 141-25-5*, 6 Aug. 1994 (DAO).

The nearest sites in the Yukon Territory known to Cody (1996) are adjacent to the Canol Road about 450 kilometers to the northwest. To the north it is known from the central Mackenzie Mountains in western District of Mackenzie (Porsild and Cody 1980).

Saxifraga hieracifolia Waldst. and Kit., Hawkweed-leaved Saxifrage — YUKON: lichen alpine tundra with scattered *Betula pumila* and *Salix* on broken limestone shelf, La Biche Mountain Range, 4550 ft., 60°33'19"N 124°29'12"W, *Sharp & Cowell 3158*, 6 Aug. 1994 (DAO); lichen/moss alpine tundra at peak of mountain, same locality, 4775 ft., *Sharp & Cowell 3114*, 6 Aug. 1994 (DAO); rich alpine meadow in south-facing seepage area, *Senecio triangularis-Aconitum*-willow shrub, La Biche Mountain Range, 4650 ft., 60°33'19"N 124°29'12"W, *Sharp & Cowell 3153*, 6 Aug. 1994 (DAO).

Elsewhere in the Yukon Territory this species is only known west of longitude 134°30'W where it is found in arctic-alpine situations. The nearest known location in the Territory to the sites recorded above is about 650 kilometers to the northwest; however, it is known in the Mackenzie Mountains of western District of Mackenzie.

Saxifraga hirculus L., Yellow Marsh Saxifrage — YUKON: La Biche River area, 60°33'N 124°33'W, *G. Brunner 142-25-16*, 6 Aug. 1994 (DAO); *Salix reticulata*/*Petasites*/moss/lichen on south-facing alpine tundra slope, La Biche Mountain Range, 61°33'20"N 124°30'02"W, *Sharp & Cowell 3197*, 8 Aug. 1994 (DAO); rich alpine meadow in south-facing seepage area, *Senecio triangularis-Aconitum*-willow shrub, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell 3152*, 6 Aug. 1994 (DAO).

In southern Yukon Territory the nearest known locality for this species is just west of longitude 137°W, about 700 kilometers west of the locality cited above. To the northeast it is known from the central Mackenzie Mountains of western District of Mackenzie (Porsild and Cody 1980).

Saxifraga lyallii Engler ssp. *hultenii* (Calder & Savile) Calder and Taylor — YUKON: rich alpine meadow in south-facing seepage area, *Senecio triangularis-Aconitum*-willow shrub, La Biche Mountain Range, 60°33'19"N 124°29'12"W, 4650 ft., *Sharp & Cowell 3145*, 6 Aug. 1994, (DAO).

The site reported above lies about 275 km east of the nearest known site in southern Yukon Territory west of Watson Lake. To the north it is known in the Mackenzie Mountains in southwestern District of Mackenzie (Porsild and Cody 1980).

Saxifraga nelsoniana D. Don ssp. *porsildiana* (Calder & Savile) Hultén — YUKON: Quartz Creek, 60°21'N 127°57'W, *C. Zoladeski 265-1-2*, 23 July 1994 (DAO); La Biche River area, 60°33'N 124°32'W, 1470 m, *G. Brunner 144-28-1*, 6 Aug. 1994 (DAO); boulder field on north-facing slope, near main peak of Mt. Merrill, 60°08'03"N 124°41'30"W, *Sharp et al. 3227*, 9 Aug. 1994 (DAO).

The nearest site to the above in the Yukon Territory known to Cody (1996) lies about 300 kilometers to the northwest; however, it is known from the Mackenzie Mountains in southwestern District of Mackenzie to the east (Porsild and Cody 1980).

Saxifraga serpyllifolia Pursh, Thyme-leaved Saxifrage — YUKON: alpine near mining site, Groundhog Mountain, South Canol Road, 61°38'00"N 132°48'00"W, *B. Bennett 97-55*, 3 July 1995 (DAO).

This is the easternmost site yet known in the Yukon Territory. It is an extension of the known

range of about 200 km northeast from an area just north of the British Columbia border.

Saxifraga tricuspidata Rottb., Prickly Saxifrage — YUKON: lichen/moss alpine tundra at peak of mountain, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell 3120*, 6 Aug. 1994 (DAO).

Cody (1996) reported this common species only as far east in the Yukon Territory as about longitude 127°15'W. The specimen cited above extends the known range about 185 kilometers to the east near the District of Mackenzie border.

ROSACEAE

Dryas hookeriana Juz., Hooker's Mountain Avens — YUKON: abundant on tundra, Mount Haldane, 63°52'N 135°46'W, *R. Rosie 1801*, 24 July 1986 (DAO).

Cody (1996) reported this species in the Yukon Territory in the extreme southwest, adjacent to the Bonnet Plume River in the central east, by the upper Canol Road, and in the vicinity of Frances Lake. The specimen cited above is between the Bonnet Plume River and locations in the southwest of the Territory.

Geum macrophyllum Willd. ssp. *perincisum* (Rydb.) Hultén, Large-leaved Avens — YUKON: riverbed in floodplain, La Biche River, 60°04'43"N 124°02'14"W, *B. Bennett 95-154a*, 10 June 1995 (DAO); Big Whitefish Lake, Old Crow Flats, 68°11'08"N 140°15'49"W, *B. Bennett 95-427*, 13 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory as far east as about longitude 127°15'W and disjunct to the Porcupine River from the lower Dempster Highway. The first specimen cited above is an extension of the known range of about 200 kilometers to the east. The second specimen is the northernmost yet known and is a northward extension of the known range of about 60 kilometers.

Geum triflorum Pursh, Prairie Smoke — YUKON: dry gravel and sandy soil, Beaver River-Larsen Creek area, 60°10'06"N 125°05'54"W, *B. Bennett 95-305*, 21 June 1995 (DAO).

Cody (1994) reported this species from the Takikini River area and near Minto and recommended that it should be added to the list of rare plant species in the Yukon Territory (Douglas et al. 1981). The specimen cited above is the third reported for the Territory; although lacking a flowering stem, it is readily identifiable.

Potentilla diversifolia Lehm., Blue-leaved Cinquefoil — YUKON: *Abies lasiocarpa*/feathermoss krummholz forest on west-facing alpine slope, La Biche Mountain Range, 4700 ft., *Sharp & Cowell 3203*, 8 Aug. 1994 (DAO).

The nearest known site in the Yukon Territory is in the vicinity of Frances Lake about 200 kilometers

to the west of the La Biche Mountain site above (Cody 1996). It is known from the nearby Mackenzie Mountains in southwestern District of Mackenzie (Porsild and Cody 1980).

Potentilla hyperarctica Malte s.l., Arctic Cinquefoil — YUKON: ca. 30 kilometers N of campground on Nahanni Range Road, 61°41.69'N 128°17.62'W, *C. Zoladeski*, 11 Aug. 1995 (DAO); alpine lichen tundra, top of small mountain ridge W of Gusty Lakes, 60°21.41'N 126°33.05'W, *Zoladeski & Wilhelm*, 16 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 129°W at latitude 62°N. The specimen cited above is an extension of the known distribution of about 275 kilometers to the southeast.

Potentilla nivea L., Snow Cinquefoil — YUKON: La Biche River area, 60°33'N 124°33'W, 1400 m, *G. Brunner 141-25-2*, 6 Aug. 1994 (DAO).

The site reported above is about 250 kilometers east of the nearest locality in the vicinity of Frances Lake in southern Yukon Territory (Cody 1996); however, it is known to the east in the southern Mackenzie Mountains in southwestern District of Mackenzie.

Potentilla palustris (L.) Scop., Marsh Fivefinger — YUKON: boggy edge of beaver pond, La Biche River, 60°05'41"N 124°02'12"W, *B. Bennett 95-268B*, 17 June 1995 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 127°15'W. The specimen cited above is an extension of the known range eastward about 200 kilometers.

Potentilla uniflora Ledeb., One-flowered Cinquefoil — YUKON: La Biche River area, 60°32'N 124°30'W, *R. Mueller 155-50-1*, 6 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°15'W. The specimen cited above extends the known range about 175 kilometers to the east near the District of Mackenzie border.

Rubus arcticus L. ssp. *arcticus*, Nagoonberry — YUKON: Big Whitefish Lake, Old Crow Flats, 68°11'08"N 140°15'49"W, *B. Bennett 95-426a*, 13 Aug. 1995 (DAO).

Cody (1996) reported this subspecies in the Yukon Territory only as far north as about latitude 65°N adjacent to the Dempster Highway.

Rubus arcticus L. ssp. *acaulis* (Michx.) Focke — YUKON: marshy area under shady mature spruce forest, Beaver River-Larsen Creek area, 60°10'26"N 125°02'12"W, *B. Bennett 95-280a*, 18 June 1985 (DAO); small bog, La Biche River, 60°02'59"N

123°59'26"W, *B. Bennett* 95-216b, 14 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only about as far east as longitude 129°W. The specimens cited above extend the known range eastward about 275 kilometers.

Rubus chamaemorus L., Cloudberry, Baked-apple Berry — YUKON: Beaver River, 60°11'N 125°09'W, *G. Brunner* 20-31-1, 10 Aug. 1994 (DAO); roadside-edge of *Picea mariana*, *Ledum groenlandicum* bog, La Biche River, 60°02'00"N 123°55'00"W, *B. Bennett* 95-231b, 15 June 1995.

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°30'W. The specimen cited above is an extension of the known range eastward about 200 kilometers.

Rubus pubescens Raf., Dwarf Raspberry — YUKON: widespread, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-179, 9 June 1997 (DAO) and 97-254, 10 June 1997 (DAO); Beaver River, 60°11'N 125°09'W, 450 m, *G. Brunner* 17-29-2, 10 Aug. 1994 (DAO); gravel bar of river, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-108e, 5 June 1995 (DAO); in moist, flat, *Populus tremuloides* lowland, La Biche Camp, 60°03'07"N 124°04'03"W, *B. Bennett* 97-324, 13 June 1997 (DAO); alluvial *Picea glauca*/*Rosa acicularis*/*Cornus canadensis*/feathermoss forest, bank of Liard River S of Upper Liard village, 60°02.90'N 128°53.41'W, *Staniforth et al.*, 18 Aug. 1995 (DAO); edge of warm spring, Frances Lake, 61°34'N 129°06'W, *R. Rosie* 1941, 18 July 1996 (DAO).

Douglas et al. (1981) included this species in their treatment of rare plants in the Yukon Territory on the basis of specimens collected in the vicinity of the Coal River springs at approximately 60°09'N 127°26'W. The specimens cited above extend the known range in the Territory to west of Watson Lake and about 200 kilometers east and 175 kilometers to the north.

Sanguisorba officinalis L., Great Burnet — YUKON: roadside ditch, Km 203.2 Dempster Hwy., *G. Brunner* 250, 28 June 1996 (DAO).

North of latitude 64°N this species was only known from adjacent to the Yukon and Porcupine rivers. The specimen cited above is between these two areas.

Spiraea beauverdiana Schneid., *Spiraea* — YUKON: boulder field on north-facing slope, near main peak of Mt. Merrill, 60°08'03"N 124°41'30"W, 4750 ft., *Sharp et al.* 3228, 9 Aug. 1994 (DAO).

The locality cited above lies about 400 kilometers southeast of the nearest locality mapped by Cody (1996). To the east it is known in the Mackenzie Mountains in western District of Mackenzie (Jeffrey 1961; Porsild and Cody 1980).

FABACEAE (LEGUMINOSAE)

Astragalus adsurgens Pall. ssp. *robustior* (Hook.) Welsh, Standing Milk-vetch — YUKON: roadside sandy gravel, Alaska Hwy. 2 km E of Hwy. 37 junction, 60°01'30"N 128°02'20"W, *B. Bennett* 97-148, 5 July 1996 (DAO).

This subspecies was previously known in the Yukon Territory only in the vicinity of Ross River (Cody 1996). The specimen cited above is an extension of the known range of about 350 kilometers to the southeast.

Astragalus alpinus L., Alpine Milk-vetch — YUKON: gravel bar of river, La Biche River, 60°04'45"N 124°02'W, *B. Bennett* 95-108a, 5 June 1995 (DAO); disturbed gravel along roadside, 60°04'45"N 124°02'09"W, *B. Bennett* 95-203, 13 June 1995 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 127°35'W. The specimens cited above extend the known distribution eastward about 225 kilometers.

Astragalus americanus (Hook.) M. E. Jones, American Milk-vetch — YUKON: old roadbed, Liard River, 60°01'25"N 128°37'18"W, *B. Bennett* 97-62, 30 June 1996 (DAO).

The specimen cited above is an extension of the known range in the Yukon Territory of about 200 kilometers east from a site at about longitude 127°15'W.

Astragalus cicer L., Chick-pea Milk-vetch — YUKON: roadside in moist clay and sand, La Biche River, 60°01'30"N 123°52'30"W, *B. Bennett* 95-224, 15 June 1995 (DAO).

This introduced species is new to the flora of the Yukon Territory. It was first reported as occurring in North America from the vicinities of Brandon, Manitoba, and Stavely, Alberta, by G. A. Stevenson (1965). Since then, in Canada, it has been reported from Université Laval, Ste-Foy, Québec (Cayouette et al. 1983), Ontario (without locality) (Morton and Venn 1990 and Cody collections at DAO) and Coquitlam and Williams Lake, British Columbia (Douglas et al. 1990). In addition to the above locality, Bennett observed this species in October 1995 (still in flower) along the windswept Haines Highway near Klukshu north of the Yukon border (photo DAO). This usually much taller, although often decumbent, with 17 to 29 lance-elliptic or oblong leaflets 0.5 to 3.5 cm, yellow flowers and inflated, ovoid to subglobose pods up to 1.4 cm long, stands out from all native *Astragalus* species in the Territory.

Astragalus eucosmus Robins., Elegant Milk-vetch — YUKON: river sand bar, La Biche River, 60°03'57"N 124°02'57"W, *B. Bennett* 95-190, 12 June 1995 (DAO); roadside gravel at forest edge, La

Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-207a, 13 June 1995 (DAO).

Cody (1996) reported this species as far east in the Yukon Territory as longitude 128°10'W. The specimens cited above extend the known distribution about 260 kilometers to the east.

Lathyrus ochroleucus Hook., Cream-flowered Peavine — YUKON: washed riverbar, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-249, 9 June 1997 (DAO); Beaver River, 60°12'N 125°09'W, 460 m, *R. Mueller* 9-2-2, 5 Aug. 1994 (DAO); edge of open forest, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-103, 5 June 1995 (DAO).

Cody (1996) described and keyed this species and suggested that it should be looked for in extreme southeastern Yukon Territory because it was known in the upper Liard River valley in southwestern District of Mackenzie. It should be added to the list of rare species of the Territory (Douglas et al. 1981).

Medicago sativa L., Alfalfa — YUKON: roadside, La Biche River, 60°01'30"N 123°52'30"W, *B. Bennett* 95-223, 15 June 1995 (DAO).

Cody (1996) reported this introduced species in the Yukon Territory only from the vicinity of Whitehorse. The specimen cited above was collected over 500 kilometers to the east.

Melilotus alba Desr., White Sweet-clover — YUKON: moist slope, La Biche River, 60°09'18"N 124°03'08"W, *B. Bennett* 95-187, 12 June 1995 (DAO).

Cody (1996) reported this introduced species in the Yukon Territory only as far east as longitude 127°44.5'W. The specimen cited above is an extension of the known range eastward about 200 kilometers.

Melilotus officinalis (L.) Lam., Yellow Sweet-clover — YUKON: roadside, La Biche River, 60°01'54"N 123°54'W, *B. Bennett* 95-230a, 15 June 1995 (DAO).

Cody (1996) reported this introduced species in the Yukon Territory only as far east as longitude 127°44.5'W. The specimen cited above is an extension of the known range eastward about 200 kilometers.

Oxytropis campestris (L.) DC. ssp. *varians* (Rydb.) Cody, Alaskan Locoweed — YUKON: La Biche River area, 60°32'N 124°30'W, *R. Mueller* 155-50-6, 6 Aug. 1994 (DAO).

Cody (1996) reported this entity in the Yukon Territory only as far east as near longitude 127°15'W. The specimen cited above extends the known range about 200 kilometers to the east near the District of Mackenzie border.

Oxytropis deflexa (Pall.) DC. ssp. *sericia* (T. and G.) Cody, Pendant-pod Locoweed — YUKON: gravel on roadside, La Biche River, 60°04'45"N

124°02'09"W, *B. Bennett* 95-206, 13 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as longitude 127°44.5'W. The specimen cited above is an extension of the known range eastward about 200 kilometers.

Oxytropis splendens Dougl., Showy Locoweed — YUKON: roadside gravel at forest edge, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-207b, 13 June 1996 (DAO).

Cody (1996) reported this species in the Yukon Territory as far east as longitude 128°10'W. The specimen cited above is an extension of the known range of about 260 kilometers to the east.

Trifolium repens L., White Clover — YUKON: riparian areas, La Biche River, 60°03'51"N 124°03'00"W, *B. Bennett* 95-181a, 12 June 1995 (DAO).

Cody (1996) reported this introduced species in the Yukon Territory only as far east as the vicinity of Watson Lake. The specimen cited above is an extension of the known range eastward of about 280 kilometers.

Vicia americana Muhl., American Vetch — YUKON: Beaver River, 60°12'N 125°09'W, 670 m, *R. Mueller* 8-1-3, 5 Aug. 1994 (DAO); roadside, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-109b, 5 June 1995 (DAO).

This species was first reported from the Yukon Territory by Scotter and Cody (1979) on the basis of a collection from near Larsen Creek, 60°12'N 125°32'W, and it was included in the list of rare plants of the Territory by Douglas et al. (1981). The specimens cited above are only the second and third collected in the Territory.

GERANIACEAE

Geranium bicknellii Britt., Bicknell's Crane's-bill — YUKON: roadside gravel, 13 km NW of Beaver Creek, 62°30'12"N 140°51'50"W, *B. Bennett* 97-30, 6 June 1996 (DAO).

This species, although it occurs north to the vicinity of Dawson, is not common in the Territory. The specimen cited above is about 150 kilometers south-southwest of Dawson near the Alaska border. Hultén (1968) knew it from only two locations in central eastern Alaska.

CALLITRICHACEAE

Callitriche anceps Fern., Two-edged Water-starwort — YUKON: in creek south of highway, unnamed creek, Robert Campbell Hwy., 60°09'32"N 128°56'45"W, *B. Bennett* 97-151, 12 July 1996 (DAO).

This species is rare in the Yukon Territory (Douglas et al. 1981) where it was previously known only from Johnson's Crossing and Mile 99 Canol Road. The collection cited above is an extension of

the known range of about 250 kilometers to the east from Johnson's Crossing.

Callitriche hermaphroditica L., Northern Water-starwort — YUKON: Old Crow Flats, Enoch Lake, 68°06'15"N 140°11'W, *B. Bennett* 95-412b (DAO), 10 Aug. 1995; Old Crow Flats, Shaeffer Lake, 68°07'45"N 140°03'30"W, *B. Bennett* 95-420 (DAO), 11 Aug. 1995.

Cody (1996) reported this wetland species only as far north as the lower Dempster Highway (Porsild 1975). The specimens cited above extend the known range in the Territory about 400 kilometers to the north.

Callitriche verna L., Spring Starwort — YUKON: mudflats in creek, E. McDonald Creek, Robert Campbell Highway, 60°10'15"N 128°55'00"W, *B. Bennett* 97-94, 3 July 1996 (DAO); submerged and emergent in clay soil at edge of slough near Beaver River, 60°10'40"N 125°08'11"W, *B. Bennett* 95-309, 21 June 1995 (DAO); La Biche River area, 60°09'15"N 123°03'15"W, *B. Bennett* 95-261d, 16 June 1995 (DAO).

Cody (1996) reported this wetland species in the Yukon Territory only as far east as the Teslin Lake area and the upper Canol Road. The specimens cited above extend the known range east and southeast about 775 kilometers.

ELATINACEAE

Elatine triandra Schk., Waterwort — YUKON: Lower Blow River Delta, 68°56'N 137°08'W, *Dickson & Allen* 5311 — correction of latitude and longitude as published in Cody (1994) (L. Dickson, personal communication).

VIOLACEAE

Viola adunca J. E. Smith, Hook-spur Violet — YUKON: *Picea glauca*, *Betula papyrifera*, *Populus balsamifera* forest, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-174, 9 June 1997 (DAO); bank of moist side channel, La Biche River, 60°04'43"N 124°02'14"W, *B. Bennett* 95-150a, 10 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 130°15'W. The specimens cited above extend the known range eastward about 375 kilometers.

Viola canadensis L. ssp. *rydbergii* (Greene) House (*V. rugulosa* Greene), Canada Violet — YUKON: common in birch, wet shady area, La Biche River, 60°03'33"N 124°01'42"W, *B. Bennett* 95-131, 7 June 1995 (DAO).

Scotter and Cody (1979) reported this violet new to the Yukon Territory on the basis of a collection from near Larsen Creek, 60°12'N 125°32'W. The specimen cited above is only the second known from the Territory.

Viola epipsila Ledeb. ssp. *repens* (Turcz.) Becker, Dwarf Marsh Violet — YUKON: *Alnus incana* thicket, 2 km east of Fantasque Lake, 60°14'19"N 124°49'55"W, *Sharp & Cowell* 3173, 7 Aug. 1994 (DAO); uncommon, on log crossing small creek, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-164, 10 June 1997 (DAO); shady, wet, mature White Spruce forest, La Biche River, 60°03'21"N 123°59'52"W, *B. Bennett* 95-201b, 13 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°20'W. The specimen cited above extends the known range in the Territory about 200 kilometers to the east.

Viola nephrophylla Greene, Northern Bog Violet — YUKON: Mount Billings, 61°19'N 128°32'W, *Zoladeski & Mueller* 191-16-1, 10 July 1994 (DAO).

This species, which was considered rare in the Yukon Territory (Douglas 1981), was previously known only from the vicinity of Watson Lake. The specimen cited above is only the second from the Territory and represents an extension of the known range of about 150 kilometers to the north.

ELAEAGNACEAE

Elaeagnus commutata Bernh., Silverberry — YUKON: small patch 10 × 10 m on river bank, La Biche River, 60°04'41"N 124°02'42"W, *B. Bennett* 95-160, 10 July 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as near longitude 133°35'W. The specimen cited above extends the known distribution about 600 kilometers to the east.

ONAGRACEAE

Circaea alpina L., Enchanter's-nightshade — YUKON: open mature forest, La Biche River, 60°03'45"N 124°01'51"W, *B. Bennett* 95-122b, 6 June 1995 (DAO); boggy *Potentilla palustris* edge of Beaver Pond, La Biche River, 60°05'4"N 124°02'12"W, *B. Bennett* 95-268A, 17 June 1995 (DAO); edge of warm spring, Frances Lake, 61°34'N 129°36'W, *R. Rosie* 1938, 18 July 1996 (DAO).

Scotter and Cody (1979) reported this species new to the Yukon Territory on the basis of a collection from hot springs and adjacent areas near the Beaver River, 60°23'N 125°34'W. The specimens cited above are the second, third and fourth known from the Territory.

Epilobium angustifolium L., Fireweed — YUKON: La Biche River area, 60°33'N 124°32'W, *G. Brunner* 151-34-1, 8 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as near longitude 127°15'W. The specimen cited above is an extension of the known range of about 175 kilometers to the east.

Epilobium hornemannii Rchb., Hornemann's Willowherb — YUKON: La Biche River area, 60°33'N 124°32'W, *G. Brunner* 144-28-2, 6 Aug. 1994 (DAO); same locality, *G. Brunner* 151-34-4, 8 Aug. 1994 (DAO); rich alpine meadow in south-facing seepage area, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3154, 6 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as near longitude 127°15'W. The specimens cited above are an extension of the known range of about 175 kilometers to the east.

Epilobium lactiflorum Haussk., White-flowered Willowherb — YUKON: La Biche River area, 60°33'N 124°31'W, 1450 m, *R. Mueller* 161-56-6, 8 Aug. 1994 (DAO).

This specimen, collected in the extreme southeast of the Yukon Territory, was from a site about 450 kilometers from localities on the Canol Road (Cody 1996); however, it is known in the Mackenzie Mountains of southwestern District of Mackenzie.

HIPURIDACEAE

Hippuris vulgaris L., Common Mare's-tail — YUKON: ponds on roadsides surrounded by *Picea mariana* bog, La Biche River, 60°02'36"N 123°57'26"W, *B. Bennett* 95-238b, 15 June 1995 (DAO); submergent and emergent edge of beaver pond, La Biche River, 60°09'15"N 124°03'46"W, *B. Bennett* 95-253a, 16 June 1995 (DAO); marsh edge of alpine pond near main peak of Mount Merrill, 60°07'47"N 124°41'11"W, *Sharp & Cowell* 3219, 9 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as near longitude 127°15'W. The specimen cited above extends the known range about 200 kilometers to the east.

HALORAGACEAE

Myriophyllum sibiricum Komarov (*M. exalbescens* Fern.), Siberian Water-milfoil — YUKON: submerged in half a metre of water, Old Crow Flats, Enoch Lake, 60°06'15"N 140°11'W, *B. Bennett* 95-409, 10 Aug. 1995 (DAO).

This is the northernmost site yet known in the Yukon Territory for this species; however, it is known to occur adjacent to the Old Crow River, south of latitude 68°N (Cody 1996).

Myriophyllum verticillatum L., Verticillate Water-milfoil — YUKON: slough off Loop Road, Upper Liard River, 60°03'56"N 128°55'09"W, *B. Bennett* 97-91b, 10 July 1996 (DAO).

This species, which was considered rare in the Yukon Territory by Douglas et al. (1981), was only known in the Territory by Cody (1996) from seven localities, all west of about longitude 133°30'W. The specimen cited above is an extension of the known range of about 250 kilometers to the east.

ARALIACEAE

Aralia nudicaulis L., Wild Sarsaparilla — YUKON: edge of forest, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-107A, 5 June 1995 (DAO); moist *Picea glauca* woodland, unnamed lake, 60°03'N 127°36'W, *W. J. Cody* 32461, 8 July 1983 (DAO).

Scotter and Cody (1979) reported this rare species new to the flora of the Yukon Territory on the basis of specimens collected near the Coal River. The specimens cited above extend the known range eastward about 200 kilometers.

Oplopanax horridus (Smith) Miq., Devil's-club — YUKON: only one plant seen, moist shaded creek-side, Lower Beaver River, 60°01'30"N 124°31'40"W, *B. Bennett* 97-200, 10 June 1997 (DAO); in mature White Spruce forest with *Rubus idaeus*, *Rosa acicularis*, *Cornus stolonifera* understory, La Biche River, 60°03'30"N 123°59'45"W, *B. Bennett* 95-213B, 14 June 1995 (DAO).

Douglas et al. (1981) knew this rare species in the Yukon Territory only from southern Kluane National Park. The specimen cited above extends the known distribution to the extreme southeast corner, a distance of about 800 kilometers.

APIACEAE

Angelica lucida L., Seacoast Angelica — YUKON: La Biche River area, 60°33'N 124°32'W, 1320 m, *G. Brunner* 148-31-2, 8 Aug. 1994 (DAO).

This species, which was considered rare in the Yukon Territory by Douglas et al. (1981), was only known in the Territory from three localities. The nearest of these was in the Itsi Range near Macmillan Pass, about 450 kilometers northwest of the site reported above. The top of the living plant at the La Biche site had been eaten by an animal.

Cicuta bulbifera L., Bulbous Water-hemlock — YUKON: Upper Coal River, 60°12'N 127°17'W, 1030 m, *C. Zoladeski* 340-2-3, 22 July 1994 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). Cody (1996) reported it from only three areas in the Territory: near Mayo, Frances Lake and a site in the vicinity of the collection cited above.

Cicuta virosa L. (*C. mackenzieana* Raup), European Water-hemlock — YUKON: in boggy area, Watson Lake area, 60°02'N 129°30'W, *R. Rosie* 1896, 15 July 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as just west of longitude 131°W. The specimen cited above from the Watson Lake area is about 350 kilometers to the southeast.

Heracleum lanatum Michx., Cow-parsnip — YUKON: on steep rocky southeast slope, Mount Haldane, 63°52'N 135°46'W, *R. Rosie* 1873A, 11 Aug. 1986 (DAO).

Cody (1996) reported this species as far north in the Yukon Territory as 63°08'N. The specimen cited above is the northernmost yet found in the Territory.

Osmorhiza depauperata Phil., Sweet Cicely — YUKON: shady *Picea glauca*, *Betula papyrifera* forest, Lower Beaver River, 60°01'30"N 124°31'40"W, *B. Bennett* 97-235, 9 June 1997 (DAO); open shady mature forest, La Biche River, 60°08'55"N 124°03'55"W, *B. Bennett* 95-262, 16 June 1995 (DAO).

Cody (1996) reported this species, which was considered rare in the Yukon Territory by Douglas et al. (1981), from only three localities in the southeast. The specimens cited above extend the known range about 90 kilometers to the east.

Podistera macounii (Coul. & Rose) Math. and Const. (*Ligusticum mutellinoides* (Crantz.) Willard ssp. *alpinum* (Ledeb.) Thell. — YUKON: in dry stony heath with *P. yukonensis*, SE of Apex Mt., Dawson Range, 62°26'N 137°57'W, elev. 5300', *R. Frisch s.n.*, June 1982 (DAO).

This collection represents an extension of the known range of about 200 kilometers east southeast of a site in Alaska plotted by Hultén (1968). Elsewhere in the Yukon Territory this species, which is considered rare in the Territory (Douglas et al. 1981), is known only in the Richardson Mountains (Cody 1996).

Podistera yukonensis Math. & Constance — YUKON: common SE of Apex Mt., 62°26'N 137°57'W, Dawson Range, elev. 5300 ft., *R. Frisch s.n.*, 9 June 1982 (DAO); also observed between Apex and Prospector Mts. only, in dry stony heath at 5000-5500 ft.

Cody (1994) extended the known range of this rare endemic from the type locality at Little Klondike River some 50 kilometers northward into the Tombstone Range of the Ogilvie Mts. The collection cited here extends the known range nearly 200 kilometers south southeast of the type locality.

Sium suave Walt., Water-parsnip — YUKON: Liard Plateau, 60°06'N 128°30'W, 810 m, *G. Brunner* 113-25-1, 25 July 1994; silty pond edge in a *Pinus contorta*, *Populus tremuloides* forest, east of McKinnon Lake, 60°02'40"N 129°13'30"W, *B. Bennett* 97-08, 18 July 1995 (DAO).

Cody (1994) recorded this species as new to the Yukon Territory on the basis of specimens collected in the Teslin Lake and Nisutlin River Delta areas. The localities cited above extend the known range eastward about 225 kilometers east of Teslin Lake.

CORNACEAE

Cornus canadensis L., Bunchberry — YUKON: on mossy *Populus balsamifera* log, La Biche River, 60°03'45"N 124°01'51"W, *B. Bennett* 95-200c, 6 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°20'W. The specimen cited above extends the known range about 200 kilometers to the east.

Cornus stolonifera Michx., Red-osier Dogwood — YUKON: edge of shaded open forest, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-102a, 5 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°20'W. The specimen cited above extends the known range about 200 kilometers to the east.

PYROLACEAE

Moneses uniflora (L.) A. Gray, One-flowered Pyrola — YUKON: on rotten *Populus balsamifera*, La Biche River, 60°03'33"N 124°01'42"W, *B. Bennett* 95-129a, 7 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°20'W. The specimen cited above extends the known range about 200 kilometers to the east.

Pyrola grandiflora Radius, Arctic Pyrola — YUKON: shady mature spruce forest, moist, with heavy moss layer, Beaver River-Larsen Creek area, 60°10'26"N 125°02'12"W, *B. Bennett* 95-279a, 18 June 1995 (DAO); shaded *Betula/Populus balsamifera/Picea glauca* forest, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-267, 11 June 1997 (DAO).

Cody (1996) reported this species, which is widespread in the Yukon Territory, only as far east as the vicinity of Watson Lake. The specimens cited above extend the known range about 250 kilometers to the east.

Pyrola minor L., Lesser Wintergreen — YUKON: old spruce log, La Biche River, 60°02'54"N 124°00'00"W, *B. Bennett* 95-210, 14 June 1995 (DAO); Mount Merrill, 60°06'N 124°45'W, *G. Brunner* 222-13-3, 9 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as the vicinity of Watson Lake. The specimen cited above extends the known range about 275 kilometers to the east.

ERICACEAE

Andromeda polifolia L., Bog Rosemary — YUKON: Beaver River-Larsen Creek area, 60°10'42'N 125°05'38"W, *B. Bennett* 95-312, 23 June 1995 (DAO).

Cody (1996) reported this species, which is widespread in the Yukon Territory, as far east as about longitude 127°30'W. The specimen cited above is an extension of the known range of about 150 kilometers to the east.

Arctostaphylos rubra (Rehd. and Wils.) Fern., Alpine Bearberry — YUKON: *Arctostaphylos/Vaccinium uliginosum*/lichen alpine tundra, W of

Gusty Lakes, 60°21.41'N 126°33.05'W, *C. Zoladeski*, 16 Aug. 1995 (DAO); Mount Merrill, 60°06'N 124°44'W, *G. Brunner* 220-10-1, 9 Aug. 1994 (DAO); Black Spruce bog with *Ledum* under-story, La Biche River, 60°02'59"N 123°59'26"W, *B. Bennett* 95-212b, 14 June 1996 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as near longitude 127°15'W. The specimen cited above is an extension of the known range of about 180 kilometers further east.

Cassiope mertensiana (Bong.) D. Don, White Mountain Heather — YUKON: on alpine tundra slope, west of Hyland River, 61°23'N 128°23'W, *R. Rosie* 1927, 25 July 1996 (DAO).

Cody (1996) described and keyed this species and suggested that it should be looked for in protected alpine situations in southern Yukon Territory. It should now be added to the list of rare plants (Douglas et al. 1981).

Chamaedaphne calyculata (L.) Moench, Leatherleaf — YUKON: mature *Picea glauca*, *Populus balsamifera* forest wet *Picea mariana* transition, La Biche River, 60°02'00"N 123°55'00"W, *B. Bennett* 95-232a, 15 June 1995 (DAO).

Cody (1996) knew this species in the Yukon Territory only as far east as about longitude 127°35'W. The specimen cited above is an extension of the known range about 200 kilometers to the east.

Ledum decumbens (Ait.) Lodd., Northern Labrador Tea — YUKON: *Arctostaphylos alpina*/lichen alpine tundra, Mt. Skonseng ridge, 60°55.32'N 127°11.44'W, *Zoladeski & Wilhelm*, 17 Aug. 1995 (DAO); *Betula glandulosa*/lichen alpine tundra, near main peak of Mt. Merrill, *Sharp et al.* 3221, 9 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as near longitude 128°20'W. The specimens cited above extend the known range of this species about 250 kilometers to the east.

Loiseleuria procumbens (L.) Desv., Alpine Azalea — YUKON: Quartz Creek, 60°20'N 127°57'W, 1550 m, *C. Zoladeski* 269-6-5, 23 July 1994 (DAO); Mount Laporte, 61°13'N 127°26'W, 1800 m, *G. Brunner* 205-21-1, 20 July 1994 (DAO); *Arctostaphylos alpina*/lichen alpine tundra on Mt. Skonseng ridge, 60°55.32'N 127°11.44'W, *Zoladeski & Wilhelm*, 17 Aug. 1995 (DAO).

With the exception of sites in the vicinity of Macmillan Pass adjacent to the Canol Road, all collections known to Cody (1996) were west of 135°W longitude. The sites reported above extend the known range about 350 kilometers to the southeast.

Rhododendron lapponicum (L.) Wahlenb., Lapland Rose-bay — YUKON: Mount Merrill, 60°06'N

124°44'W, *G. Brunner* 220-10-2, 9 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 128°15'W. The specimen cited above is an extension of the known range about 250 kilometers to the southeast.

Vaccinium caespitosum Michx., Dwarf Bilberry — YUKON: La Biche River area, 60°33'N 124°32'W, 1320 m, *R. Mueller* 162-57-1, 8 Aug. 1994 (DAO); *Pinus contorta* old burn, with *Betula glandulosa*, *Festuca altaica*/moss-lichen, 2 kilometers SE of Gusty Lakes helicopter landing point, 60°24.45'N 126°25.39'W, *C. Zoladeski*, 16 Aug. 1995 (DAO); mesic graminoid meadow with *Festuca altaica*-*Rubus acaulis*/moss-lichen, Gusty Lake, 60°28.03'N 126°29.95'W, *C. Zoladeski*, 16 Aug. 1995 (DAO); Mount Billings, 61°19'N 128°32'W, *Rosie & Zoladeski* 190-15-1, 10 July 1994 (DAO).

This species, which occurs in southern Yukon Territory as far north as latitude 62°N, was not reported by Cody (1996) from east of longitude 129°W. The specimens cited above represent an extension of the known range about 250 kilometers to the east.

Vaccinium membranaceum Dougl., Tall Blueberry — YUKON: Mount Merrill, 60°06'N 124°45'W, 1300 m, *G. Brunner* 222-13-1, 9 Aug. 1994 (DAO); Mount Merrill, 60°04'N 124°44'W, 1000 m, *R. Mueller* 227-22-5, 9 Aug. 1994 (DAO); open *Picea glauca*/shrub-rich/feathermoss forest on slope, ca. 150 m S of helicopter landing point at Gusty Lakes, 60°27.62'N 126°30.75'W, *Zoladeski et al.*, 16 Aug. 1995 (DAO); dry graminoid meadow with *Festuca altaica*, ca. 2 kilometers SE of Gusty Lakes helicopter landing point, 60°24.49'N 126°25.59'W, *Staniforth & Wilhelm*, 16 Aug. 1995 (DAO).

Cody (1996) described and keyed this species and suggested that it should be looked for in southeastern Yukon Territory because it was known from the west slope of the Liard Range of the Mackenzie Mountains in southwestern District of Mackenzie. It is new to the flora of the Territory and should be added to the list of rare plants (Douglas et al. 1981).

Vaccinium ovalifolium J.E. Smith, Oval-leaved Blueberry — YUKON: Mount Pike, 62°06'N 129°53'W, 1520 m, *C. Zoladeski* 245-4-5, 6 July 1994 (DAO).

Douglas et al. (1981) considered this species to be rare in the Yukon Territory. Cody (1996) knew it in the Territory from only four localities, the northernmost being in the vicinity of Frances Lake. The specimen cited above represents an extension of the known range northward of about 100 kilometers.

Vaccinium vitis-idaea L. ssp. *minus* (Lodd.) Hultén, Mountain Cranberry — YUKON: closed *Picea glau-*

calP. mariana forest moss understory, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-180, 10 June 1997 (DAO); *Betula glandulosa*/willow/lichen south-facing alpine slope, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3133, 6 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as approximately longitude 127°15'W. The specimens cited above are an extension of the known range of about 180 kilometers to the east.

PRIMULACEAE

Androsace septentrionalis L., Fairy-candelabra — YUKON: La Biche River, 60°05'20"N 124°02'20"W, *B. Bennett* 95-270d, 17 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as the vicinity of Watson Lake. The specimen cited above is an extension of the known range about 275 kilometers to the east.

Primula eximia Greene (*P. tschuktschorum* Kjellm. var. *arctica* (Koidz.) Fern., *P. tschuktschorum* Kjellm. ssp. *cairnsiana* Porsild) — YUKON: damp meadow by creek at timberline, upper Big Creek SE of Apex Mt., Dawson Range, elev. \pm 4500', *R. Frisch s.n.*, 9 June 1982 (DAO).

This species was previously reported in the Yukon Territory from the Richardson Mts. and near the Alaska border west of Dawson (Cody 1996). The site reported above is an extension of the known range of some 250 kilometers southeast of the site west of Dawson. Frisch also noted on his label "found locally in area southeast to Klaza Mt. from timberline to over 6000' (near maximum elevs. of mountains), mostly by creeks and seepages; some plants past full anthesis in lower sites (spring 1982 about 2 weeks late)". Klaza Mountain is about 30 kilometers southeast of the Big Creek site.

Primula mistassinica Mich., Bird's-eye Primrose — YUKON: on travertine seepage on riverbank close to river edge, Lower Coal River, 60°00'00"N 126°53'10"W, *J. Staniforth* 17, Aug. 1995 (DAO); common on turf sites by creek in woods below timberline, Upper Big Creek, Dawson Range, 62°18'N 137°53'W, *R. Frisch*, 7 June 1982 (DAO).

Cody (1996) mapped only six localities for this species that was considered rare in the Yukon Territory by Douglas et al. (1981).

Trientalis europaea L., Northern Starflower — YUKON: small bog, La Biche River, 60°02'59"N 123°59'26"W, *B. Bennett* 95-216a, 14 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as near longitude 129°W. The specimen cited above extends the known range eastward about 285 kilometers.

GENTIANACEAE

Gentiana glauca Pallas, Glaucous Gentian — YUKON: La Biche River area, 60°33'N 124°32'W, *G. Brunner* 144-28-10, 6 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 127°10'W. The specimen cited above is an extension of the known range of about 180 kilometers to the southeast.

Gentianella amarella (L.) Börner ssp. *acuta* (Michx.) J. M. Gillett, Felwort — YUKON: closed canopy *Pinus contorta* shrub thicket (burn regeneration), ca. 2 kilometers SE of Gusty Lakes helicopter landing point, 60°24.45'N 126°25.39'W, *C. Zoladeski*, 16 Aug. 1995 (DAO); meadow by roadside to Upper Gaswell, 60°07'25"N 124°06'02"W, *B. Bennett* 97-158, 16 June 1997 (DAO).

Cody (1996) reported this species in the Yukon Territory as far east as about longitude 128°30'W. The specimens cited above extend the known range about 250 kilometers to the east.

Gentianella propinqua (Richards.) J. M. Gillett ssp. *propinqua*, Four-parted Gentian — YUKON: open *Picea glauca*/shrub-rich/feathermoss forest on slope, Gusty lakes, 60°27.62'N 126°30.75', *Zoladeski et al.*, 16 Aug. 1995 (DAO); mesic graminoid meadow with *Festuca altaica*-*Rubus acaulis*/moss-lichen, Gusty Lakes, 60°28.03'N 126°29.95'W, *C. Zoladeski*, 16 Aug. 1995 (DAO); rich alpine meadow in south-facing seepage area, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3148, 6 Aug. 1994 (DAO); La Biche River area, 60°33'N 124°31'W, *R. Mueller* 158-53-2, 6 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 127°15'W. The specimens cited above extend the known distribution about 180 kilometers to the east.

BORAGINACEAE

Mertensia paniculata (Ait.) G. Don var. *paniculata*, Tall Bluebells — YUKON: edge of shaded open forest, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-105, 5 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°15'W. The specimen cited above is an extension of the known range about 175 kilometers to the east.

Myosotis alpestris Schm. ssp. *asiatica* Vestergr., Mountain Forget-me-not — YUKON: La Biche River area, 1400 m, *G. Brunner* 142-26-3, 6 Aug. 1994 (DAO).

The site reported above represents an extension of the known range in the Yukon Territory (Cody 1996) about 300 kilometers eastward and 275 kilometers southeastward; however, it is known in the Mackenzie Mountains in western District of Mackenzie.

Plagiobothrys scouleri (H. & A.) Johnston (*P. cognatus* (Greene) Johnston), Scouler's Popcorn Flower — YUKON: few plants, wet road edge near pond at Henderson Corner, east of Dawson City, *G. Brunner* 233, 9 July 1995 (DAO).

Hultén (1949) cited this introduced species from the Central Yukon River District as Dawson, Fairbanks, *Scamman 1080(H)*. However, Scamman (1940) reported *P. cognatus 1080* as Fairbanks. On 17 July 1949 Calder and Billard (3759, DAO) collected it on a sandy-gravelly area by roadside about 37 miles east of Dawson on the road to McQuesten thus verifying its presence in the region. The collection by Brunner cited above verifies the continued existence of this species in the Dawson region but it is not known elsewhere in the Yukon Territory, although it could easily be overlooked. It has also recently been introduced in Quebec (Cayouette et al. 1983).

LAMIACEAE (LABIATAE)

Dracocephalum parviflorum Nutt., American Dragonhead — YUKON: roadside gravel, Alaska Hwy., NW of Beaver Creek, 62°30'00"N 140°62'40"W, *B. Bennett 97-15*, 8 May 1996 (DAO).

The specimen cited above is an extension of the known range in the Territory of about 300 kilometers northwest of a site adjacent to the Haines Highway south of Haines Junction.

Galeopsis tetrahit L. var. *bifida* (Boenn.) Lej. and Court (*G. bifida* Boenn., Hemp-nettle — YUKON: growing in front of cabin with raspberries, Km 9 Dempster Hwy., *G. Brunner 231*, 13 Aug. 1995 (DAO); Lansing, 63°45'N 133°28'W, *B. Mitford 332*, 7 Aug. 1996 (DAO).

This taxon, which is introduced from Eurasia, is widespread across North America. Cody (1996) reported it from only one locality along the Canol Road. It is now known from three localities in the Territory.

Scutellaria galericulata L. var. *pubescens* Benth., Marsh Skullcap — YUKON: moist bank, small island in middle of unnamed lake, 60°07.5'N 127°21.5'W, *W. J. Cody 32350*, 7 July 1983 (DAO); edge of beaver pond, La Biche River, 60°05'41"N 124°02'41"W, *B. Bennett 95-265a*, 17 June 1995 (DAO).

Douglas et al. (1981) reported this rare plant in the Yukon Territory only from the Carmacks, Minto and Mayo areas. Scotter and Cody (1979) extended the known range to the southeast to the Beaver River area, 60°23'N 125°34'W. The specimens cited above extend the known range to a broader area in the southeast.

SCROPHULARIACEAE

Castilleja miniata Douglas ex Hook. — Egger (1992) extended the known range of this species

northward from the extreme south of the Yukon Territory to the west side of the Yukon River across from Dawson and suggested that it was an introduction at this site.

Castilleja raupii Pennell, Raup's Paintbrush — YUKON: La Biche River area, 60°33'N 124°32'W, *G. Brunner 144-28-7*, 6 Aug. 1994 (DAO); *Salix*/forb meadow with prominent moss groundlayer on west-facing slope, La Biche Mountain Range, *Sharp & Cowell 3211*, 8 Aug. 1994 (DAO).

With the exception of two locations about longitude 127°15'W, Cody (1996) reported this species in the Yukon Territory only west of 135°W. The specimens cited above extend the known range in the southeast about 200 kilometers to the east.

Limosella aquatica L., Water Mudwort — YUKON: riverbank, Liard River, 60°01'15"N 128°36'25"W, *B. Bennett 97-32*, 30 June 1996 (DAO).

Cody (1996) reported this rare species in the Yukon Territory from only two localities: upper Canol Road and in the vicinity of Teslin Lake. The specimen cited above, which was collected near Watson Lake, was from about 230 kilometers east of the Teslin Lake locality.

Mimulus guttatus DC., Yellow Monkeyflower — YUKON: edge of warm spring, Frances Lake, 61°34'N 129°26'W, *R. Rosie 1948*, 18 July 1996 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). The specimen cited above is the northernmost yet collected in the Territory and from about 175 kilometers north of a site near Watson Lake.

Pedicularis lanata Cham. and Schlecht., Woolly Lousewort — YUKON: Mount Merrill, *G. Brunner 220-10-4*, 9 Aug. 1994 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as just west of longitude 127°W. The specimen cited above extends the known range about 175 kilometers to the east.

Pedicularis langsдорffii Fisch. ssp. *arctica* (R. Br.) Pennell ex Hultén (*P. arctica* R. Br.), Langsdorf's Lousewort — YUKON: Mount Merrill, 60°06'N 124°44'W, 1350 m, *G. Brunner 220-10-3*, 9 Aug. 1994 (DAO); La Biche River area, 60°32'N 124°30'W, 1500 m, *R. Mueller 155-50-2*, 6 Aug. 1994 (DAO).

The sites reported above represent an extension of the known range in the Yukon Territory (Cody 1996) about 300 kilometers eastward from longitude 130°07'W.

Pedicularis macrodonta Richards. (*P. parviflora sensu* Porsild and Cody 1980)

Cody (1994) reported the first known collection of this species in the Yukon Territory as collected at Nares Lake by "F. Shmatka" 10 July 1943 (GH).

However, it was actually collected by Lieutenant F. Schwatka of the United States Army on his expedition through Yukon and Alaska in 1883 (C. A. Firth personal communication 1997).

Veronica wormskjoldii R. and S., Alpine Speedwell — subalpine mixed meadow, Mt. Skonseng ridge, 60°55.55'N 127°11.47'W, *Staniforth & Wilhelm*, 17 Aug. 1995 (DAO); La Biche River area, 60°33'N 124°31'W, *R. Mueller* 158-53-9, 6 Aug. 1994 (DAO).

Cody (1996) reported this species which is widespread in the Yukon Territory south of 65°N latitude only as far east as about longitude 128°10'W. The specimens cited above extend the known range in the southeast about 225 kilometers to the east.

LENTIBULARIACEAE

Utricularia minor L., Lesser Bladderwort — YUKON: La Biche River, 60°03'21"N 123°59'52"W, *B. Bennett* 95-243, 15 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory from only four localities: southern Dempster Highway, Mayo area, southern Canol Road near Johnson's Crossing and east of Watson Lake. Douglas et al. (1981) did not include it in the list of rare plants because of its widespread circum-boreal distribution. The specimen cited above extends the known distribution about 260 kilometers to the east.

PLANTAGINACEAE

Plantago canescens Adams, Arctic Plantain — YUKON: highway embankment in rocky gravel near small pond at end of Swan Lake, Alaska Hwy., NW of Beaver Creek, 62°32'37"N 140°53'12"W, *B. Bennett* 97-17, 8 May 1996 (DAO).

The collection cited above is an extension of the known range in the Territory of about 175 km to the northwest from Kluane Lake. It is, however, known to the west in Alaska.

RUBIACEAE

Galium brandegei Gray, Bedstraw — YUKON: grass/sedge meadow in valley of La Biche River, La Biche Mountain Range, 60°31'12"N 124°43'58"W, 2700 ft., *Sharp & Cowell* 3192, 8 Aug. 1994 (DAO); *Alnus incana* thicket, 2 km east of Fantasque Lake, 60°14'19"N 124°49'55"W, 2420 ft., *Sharp & Cowell* 3172, 7 Aug. 1994.

Cody (1996) reported this species in the Yukon Territory from a single collection adjacent to the Old Crow River (*Nagy et al.* 74-558, *Sphagnum* bog, 68°01'N 139°48'W) from whence it was reported by Nagy et al. (1979) as new to the Territory. The collections cited above are from the extreme southeast about 1200 kilometers from the Old Crow River area.

Galium trifidum L., Small Bedstraw — YUKON: lakeside, Enoch Lake, Old Crow Flats, 68°05'05"N 140°09'50"W, *B. Bennett* 95-401, 9 Aug. 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory as far north as about latitude 67°48'N. The specimen cited above is the northernmost yet recorded in the Territory.

CAPRIFOLIACEAE

Lonicera dioica L. var. *glaucescens* (Rydb.) Butters, Glaucous-leaved Honeysuckle — YUKON: riverbank, La Biche River, 60°08'55"N 124°03'32"W, *B. Bennett* 95-249, 16 June 1995 (DAO); open, mature *Picea glauca* forest, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-277, 9 June 1997 (DAO).

Cody (1996) described and keyed this species, which is known in British Columbia north to the Liard Hotsprings and in southwestern District of Mackenzie north to Fort Simpson (Porsild and Cody 1980), and suggested that it would be found in the Yukon Territory. It should be added to the list of rare plants in the Territory (Douglas et al. 1981).

ADOXACEAE

Adoxa moschatellina L., Moschatel — YUKON: dry river course with *Chrysosplenium tetrandrum*, La Biche River, 60°08'28"N 124°03'20"W, *B. Bennett* 95-142, 8 June 1995 (DAO); wet, mature White Spruce forest, La Biche River, 60°03'21"N 123°59'52"W, *B. Bennett* 95-201a, 13 June 1995 (DAO); La Biche River area, 60°33'N 124°32'W, *G. Brunner* 151-34-8, 8 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 129°W. The specimens cited above extend the known distribution about 290 kilometers to the east.

VALERIANACEAE

Valeriana sitchensis Bong., Valerian — YUKON: *Abies lasiocarpa*/feathermoss krummholz forest on west-facing alpine slope, La Biche Mountain Range, 60°33'20"N 124°30'02"W, 4700 ft., *Sharp & Cowell* 3204, 8 Aug. 1994 (DAO); subalpine mixed meadow on Mt. Skonseng ridge, 60°55.55'N 127°11.47'W, *Staniforth & Wilhelm*, 17 Aug. 1995 (DAO).

The localities cited above extend the known range about 200 kilometers to the southeast of sites in southeastern Yukon Territory mapped by Cody (1996). To the north it is known from the Mackenzie Mountains in western District of Mackenzie.

ASTERACEAE (COMPOSITAE)

Achillea sibirica Ledeb., Siberian Yarrow — YUKON: shaded open forest, La Biche River, 60°04'45"N 124°02'09"W, *B. Bennett* 95-106a, 5 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 127°30'W. The specimen cited above extends the known range about 200 kilometers to the east.

Agoseris aurantaica (Hook.) Greene, Mountain Dandelion — YUKON: *Salix*/forb meadow with prominent moss groundlayer on west-facing alpine slope, La Biche Mountain Range, 60°33'20"N 124°30'02"W, *Sharp & Cowell* 3213, 8 Aug. 1994 (DAO); La Biche River area, 60°33'N 124°31'W, 1450 m, *R. Mueller* 161-56-4, 8 Aug. 1994 (DAO); La Biche River area, 60°33'N 124°12'W, 1200 m, *G. Brunner* 145-29-3, 1200 m, *G. Brunner* 145-29-3, 6 Aug. 1994 (DAO); mesic graminoid meadow 600 m ENE of helicopter landing point at Gusty Lakes, 60°28.03'N 126°29.95'W, *C. Zoladeski*, 16 Aug. 1995 (DAO).

The localities cited above are situated up to 250 kilometers east of a site mapped by Cody (1996) west of Watson Lake. It also occurs in the Mackenzie Mountains of western District of Mackenzie to the north (Porsild and Cody 1980).

Antennaria howellii Greene ssp. *canadensis* (Greene) Bayer, Field Pussytoes — YUKON: roadside, unnamed creek, 60°09'32"N 128°59'12"W, *B. Bennett* 97-96, 12 July 1996 (DAO).

Bayer in Cody (1996) reported this subspecies in the Yukon Territory only from Alaska Highway Km 949.5, 60°01'N 127°44.5'W (Cody 32467). The specimen cited above extends the known distribution about 75 kilometers to the west.

Arnica griscomii Fern. ssp. *frigida* (C. A. Mey.) S. J. Wolf, Northern Arnica — YUKON: *Vaccinium vitis-idaea* — *V. uliginosum* — *Salix reticulata*/moss-lichen slopes ca. 30 kilometers N of camp ground on Nahanni Range Road, 61°41.69'N 128°17.62'W, *C. Zoladeski*, 11 Aug. 1995 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 132°15'W. The specimen cited above is an extension of the known range about 200 kilometers to the east.

Arnica lessingii Greene, Purple Arnica — YUKON: rich alpine meadow in south-facing seepage area, La Biche Mountain Range, 60°33'19"N 124°29'12"W, 4650 ft., *Sharp & Cowell* 3143, 6 Aug. 1994 (DAO); La Biche River area, 60°33'N 124°32'W, 1470 m, *G. Brunner* 144-28-4, 6 Aug. 1994 (DAO).

The localities cited above are about 225 kilometers east of a site west of Watson Lake mapped by Cody (1996). To the north it is found in the Mackenzie Mountains of western District of Mackenzie (Porsild and Cody 1980).

Aster ciliolatus Lindl., Fringed Aster — YUKON: upland area above a slough, La Biche River area, 60°04'43"N 124°02'14"W, *B. Bennett* 95-153, 10 June 1995 (DAO).

Scotter and Cody (1979) reported this species as new to the Yukon Territory on the basis of specimens from the Larsen Creek and Beaver River areas and it was included as a rare plant by Douglas et al.

(1981). The specimen cited above is from the third known locality in the southeast.

Aster sibiricus L., Arctic Aster — YUKON: on pathway in open under mature spruce forest, La Biche River area, 60°09'21"N 123°04'07"W, *B. Bennett* 95-263a, 16 June 1995 (DAO); mature spruce forest, Beaver River-Larsen Creek area, 60°10'08"N 125°01'36"W, *B. Bennett* 95-285a, 19 June 1995 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 127°15'W. The specimens cited above extend the known range about 200 kilometers to the east.

Centaurea maculosa Lam., Spotted Knapweed — YUKON: roadside ditches, entrance to Kluane R.V. Park, Haines Junction, *L. Freese*, Aug. 1995 (DAO).

This species, which is frequent in southern British Columbia east of the Coast-Cascade Mountains (Douglas et al. 1981), is an introduction from Eurasia. It is new to the flora of the Yukon Territory. It is a biennial or short-lived perennial with branched stems up to 90 cm high with alternate leaves deeply cut into narrow divisions, numerous heads with bracts black-fringed at the top and purple or rarely white flowers.

Cirsium arvense (L.) Scop., Canada Thistle — YUKON: roadside ditch, dry gravel, Km 223.8 Haines Hwy., west side, *L. Freese*, Aug. 1995 (DAO).

This species, which is naturalized from Europe despite its common name, is a ubiquitous weed of cultivated and waste ground. It is new to the flora of the Yukon Territory. To the west Hultén (1968) has mapped it from the vicinity of Anchorage, and to the east Porsild and Cody (1980) knew it only from Fort Simpson in the District of Mackenzie. It may be separated from the only other *Cirsium* found in the Territory as follows:

- A. Native, monoecious, biennial, stems 25-70 cm tall, leaves sparsely pubescent above, tomentose to villous below, heads 3 or 4 cm high in a compact cluster *C. foliosum*
- A. Introduced, dioecious, perennial with a deeply buried rhizome, stems usually shorter, leaves glabrous, heads several to many in a much branched panicle *C. arvense*

Crepis elegans Hook., Elegant Hawksbeard — YUKON: sand and gravel over clay, river bar, Larsen Creek, 60°10'06"N 125°01'57"W, *B. Bennett* 95-272, 18 June 1995 (DAO); riverbar, Lower Beaver River, 60°02'N 124°31'40"W, *B. Bennett* 97-279, 11 June 1997 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 127°30'W. The specimens cited above extend the known range about 185 kilometers to the east.

Crepis tectorum L., Annual Hawk's-beard — YUKON: riverbank in disturbed floodplain, La Biche River area, 60°04'43"N 124°02'14"W, *B. Bennett* 95-154b, 10 June 1995 (DAO); roadside, La Biche River 60°04'45"N 124°02'09"W, *B. Bennett* 95-205a, 13 June 1995 (DAO).

Cody (1996) reported this introduced weedy species in the Yukon Territory as far east as about longitude 127°30'W. The specimens cited above extend the known range about 200 kilometers to the east.

Erigeron acris L. ssp. *politus* (Fries) Schinz & Keller, Bitter Fleabane — YUKON: dry pond margin surrounded by Black Spruce bog, La Biche River, 60°03'06"N 123°59'35"W, *B. Bennett* 95-235b, 15 June 1995 (DAO); sandy bank on slope above old channel of Larsen Creek, 60°10'01"N 125°01'23"W, *B. Bennett* 95-292, 19 June 1995 (DAO); Old Crow Flats, 68°05'N 140°09'53"W, *B. Bennett* 95-408 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east as about longitude 127°20'W. The southeast Yukon specimens cited above extend the known range about 200 kilometers to the east; the Old Crow Flats specimen is from the northernmost known locality.

Erigeron humilis Graham, Arctic Daisy — YUKON: La Biche River area, 60°33'N 124°31'W, 1530 m, *R. Mueller* 158-53-6, 6 Aug. 1994 (DAO).

The locality cited above is situated about 250 kilometers east of a site mapped by Cody (1996) near Frances Lake. To the north it occurs in the Mackenzie Mountains of western District of Mackenzie (Porsild and Cody 1980).

Erigeron philadelphicus L., Philadelphia Fleabane — YUKON: edge of warm spring, Frances Lake area, 61°34'N 129°26'N, *R. Rosie* 1907, 18 July 1996 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). The specimen cited above is the northernmost yet found and is an extension of the known range northward from near the British Columbia border of about 175 kilometers.

Hieracium gracile Hook., Slender Hawkweed — YUKON: *Phyllodoce empetriformis* alpine heath, Mt. Skonseng ridge, 60°55.35'N 127°11.79'W, *C. Zoladeski*, 17 Aug. 1995 (DAO); wetland SE of Watson Lake, 60°03'02"N 128°38'39"W, *B. Bennett* 97-146, 2 July 1996 (DAO).

The nearest sites in the Yukon Territory known to Cody (1996) were by the Canol Road. The specimen cited above is an extension of the known range of about 325 kilometers to the east.

Hieracium triste Willd., Mourning Hawkweed — YUKON: La Biche River area, 60°33'N 124°32'W, 1470 m, *G. Brunner* 144-28-8, 6 Aug. 1994 (DAO).

The locality cited above is about 225 kilometers east of a site in the vicinity of Frances Lake. To the north it occurs in the Mackenzie Mountains of western District of Mackenzie (Porsild and Cody 1980).

Hieracium umbellatum L., Narrow-leaved Hawkweed — YUKON: dry *Populus balsamifera* forest, La Biche River, 60°09'09"N 124°03'09"W, *B. Bennett* 95-261b, 16 June 1995 (DAO).

Cody (1996) reported this rare species in the Yukon Territory from only three localities in the southeast and a possible introduction in the vicinity of Dawson. The locality cited above extends the known range about 75 kilometers to the east.

Petasites frigidus (L.) Fries ssp. *frigidus*, Sweet Coltsfoot — YUKON: marsh edge of alpine pond, near main peak of Mount Merrill, 60°07'47"N 124°41'11"W, *Sharp & Cowell* 3218, 9 Aug. 1994 (DAO).

Cody (1996) reported this widespread plant in the Yukon Territory only as far east as about longitude 131°15'W in the extreme south. The specimen cited above is an extension of the known range about 425 kilometers to the east.

Petasites frigidus (L.) Fries ssp. *nivalis* (Greene) Cody, Sweet Coltsfoot — YUKON: La Biche River area, 60°33'N 124°32'W, *G. Brunner* 152-35-1, 8 Aug. 1994 (DAO).

Cody (1996) reported this subspecies as far east in the Yukon Territory as about longitude 127°15'W. The specimen cited above is an extension of the known range about 175 kilometers to the east.

Senecio lugens Richards., Black-tipped Groundsel — YUKON: open spruce bog, Beaver River-Larsen Creek area, 60°10'20"N 125°02'19"W, *B. Bennett* 95-287, 19 June 1995 (DAO).

Cody (1996) reported this widespread species in the Yukon Territory only as far east in the Territory as about longitude 127°20'W. The specimen cited above extends the known range about 140 kilometers to the east.

Senecio pauciflorus Pursh, Rayless Alpine Butterweed — YUKON: mesic graminoid meadow, 600 m ENE of helicopter landing point at Gusti Lake, *C. Zoladeski*, 16 Aug. 1995 (DAO); roadside ditch, La Biche River, 60°02'36"N 123°57'27"W, *B. Bennett* 95-239b, 15 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 129°10'W. The specimen cited above is an extension of the known range about 300 kilometers to the east.

Senecio yukonensis A.E. Porsild, Yukon Groundsel — YUKON: Quartz Creek, 60°21'N 127°57'W, *C. Zoladeski* 267-4-2, 23 July 1994 (DAO); lichen/moss alpine tundra at peak of mountain, La Biche Mountain Range, 60°33'19"N 124°29'12"W, *Sharp & Cowell* 3121, 6 Aug. 1994 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about longitude 128°45'W. The specimens cited above extend the known range about 260 kilometers to the east.

Solidago canadensis L. var. *salebrosa* (Piper) Jones, Goldenrod — YUKON: gravelly soil, mats of *Dryas* and medium shrubs, in open mature White Spruce, small river island in lower Coal River, 60°07'36"N 127°08'03"W, *J. Staniforth* 15a, 26 Aug. 1995 (DAO).

This species was considered rare in the Yukon Territory by Douglas et al. (1981). Cody (1994) showed that it is much more widely spread than previously recorded. The location cited above is between 62°45'N 135°45'W and 60°05'N 129°40'W plotted by Cody (1996).

Solidago simplex Knuth, Spike-like Goldenrod — YUKON: sandy gravelly exposed flat, Beaver River-Larsen Creek area, 60°10'36"N 125°03'128"W, *B. Bennett* 95-283b, 18 June 1995 (DAO).

Cody (1996) reported this species in the Yukon Territory only as far east as about 127°10'W. The specimen cited above extends the known range about 140 kilometers to the east.

Sonchus arvensis L. ssp. *uliginosus* (Bieb.) Nyman, Perennial Sow-thistle — YUKON: gravelly roadside, Alaska Highway, Whitehorse, near Valle, 60°43'20"N 135°07'00"W, *B. Bennett* 97-115, 23 Aug. 1996 (DAO).

Cody (1994) reported this introduced weedy species from four widely separated areas in southern Yukon Territory. The specimen cited above is from about 150 kilometers east of the nearest previously known location.

Tanacetum vulgare L., Common Tansy — YUKON: roadside ditches, 100 m north of Kathleen Lake Lodge, Haines Hwy. (ca Km 133), *L. Freese*, 7 Aug. 1995 (DAO).

This species, which is introduced from Europe, occurs in Canada from Newfoundland to British Columbia and south into the United States. This is the first record of its occurrence in the Yukon Territory. It is a perennial plant with smooth, erect stems up to 1 m high, once to twice pinnately divided leaves, and a dense flat-topped corymb with yellow flowers lacking ligules.

Tragopogon dubius Scop., Yellow Salsify — YUKON: roadside ditches, Km 229 to 229.6 Haines Road, *L. Freese*, 25 July 1995 (DAO).

This species, which now occurs from Nova Scotia to British Columbia, is an introduction from Europe. It is new to the flora of the Yukon Territory. It is a perennial with milky juice, erect stems up to 1 m high, entire grass-like clasping leaves contracting abruptly into long tips, large solitary heads with ligulate pale yellow flowers shorter than the bracts and seeds tapering into a slender beak with plumose pappus.

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Notes

Distribution of the Wood Frog, *Rana sylvatica*, in Labrador: An Update

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Chubbs, Tony E., and Frank R. Phillips. 1998. Distribution of the Wood Frog, *Rana sylvatica*, in Labrador: an update. *Canadian Field-Naturalist* 112(2): 329–331.

The distribution of the Wood Frog (*Rana sylvatica*) in Labrador is limited to two areas of occurrence in north western and south central Labrador. Here we report two new records, narrowing the distribution gap of amphibians in Labrador and extending the northeastern distribution of the Wood Frog.

Key Words: Wood Frog, *Rana sylvatica*, amphibian, distribution, range, Labrador.

To date, only six species of amphibians have been confirmed for Labrador: the Blue-spotted Salamander (*Ambystoma laterale*); the Northern Two-lined Salamander (*Eurycea bislineata*); the American Toad (*Bufo americanus*); the Mink Frog (*Rana septentrionalis*); the Northern Leopard Frog (*Rana pipiens*); and the Wood Frog (*Rana sylvatica*). Information on the status and distribution of these amphibians remains scanty, while reports of the Eastern Redback Salamander (*Plethodon cinereus*) and the Spring Peeper (*Hyla crucifer*) remain hypothetical (Maunder 1983, 1997). The distribution of the Wood Frog in Labrador is poorly documented, with only two known areas of occurrence so far recorded. Six previous records (Figure 1), document the occurrence of the Wood Frog in Labrador; in the western region near Schefferville and in the Lake Melville area (Backus 1954; Harper 1956; Bleakney 1958; Maunder 1983, 1997). There are additional records from adjacent northern Québec (Bleakney 1958; Bider and Matte 1996). This note documents two new Labrador records for the Wood Frog which extend its distribution to the northeast.

Our sightings were recorded during a sampling program to monitor possible hydrocarbon accumulation near Camera Targets used by Low Level flying aircraft training at Goose Bay, Labrador during 1995 and 1996. We opportunistically examined bogs and still waters at 22 sites for evidence of amphibians (Figure 1). Unfortunately, our sampling program in both years was conducted during September, when frogs are often not conspicuous. On 4 September

1995 we hand collected a single Wood Frog in long sedges (*Carex* sp.) at the edge of a sphagnum bog north of the Kanairiktok River (Figure 1, location A) in central Labrador (54°25.7'N, 62°30.9'W). The specimen was preserved in ethanol and deposited in the Newfoundland Museum (NFM No. 95-001) where it was identified by J. Maunder as being a juvenile Wood Frog. On 9 September 1996 on a small tributary of the Adlatok River (Figure 1, location B), a single Wood Frog was sighted on the edge of a beaver pond (55°02.2'N, 60°53.4'W). The frog leaped into the pool and concealed itself in submergent vegetation, avoiding capture. Both sites were characterized by *Pleurozium* — Black Spruce (*Picea mariana*) and *Sphagnum* — Black Spruce forest and were located in the mid subarctic forest ecoregion (Meades 1990*). Shrub cover consisted primarily of Labrador Tea (*Ledum groenlandicum*) and willow (*Salix* sp.) interspersed with Larch (*Larix laricina*) trees.

Maunder (1983) suggested the apparent gap in the distribution of the Wood Frog could be related to geological and/or hydrological conditions which are also reflected in the discontinuous distribution of freshwater molluscs, particularly gastropods. Our new records suggest that the appearance of widely separated localities may have been an artefact of low sampling effort in these remote uninhabited regions and/or naturally occurring low densities of amphibians along the northernmost portion of their range. The northern distribution of the Wood Frog (and possibly other amphibians) appears to consist of iso-

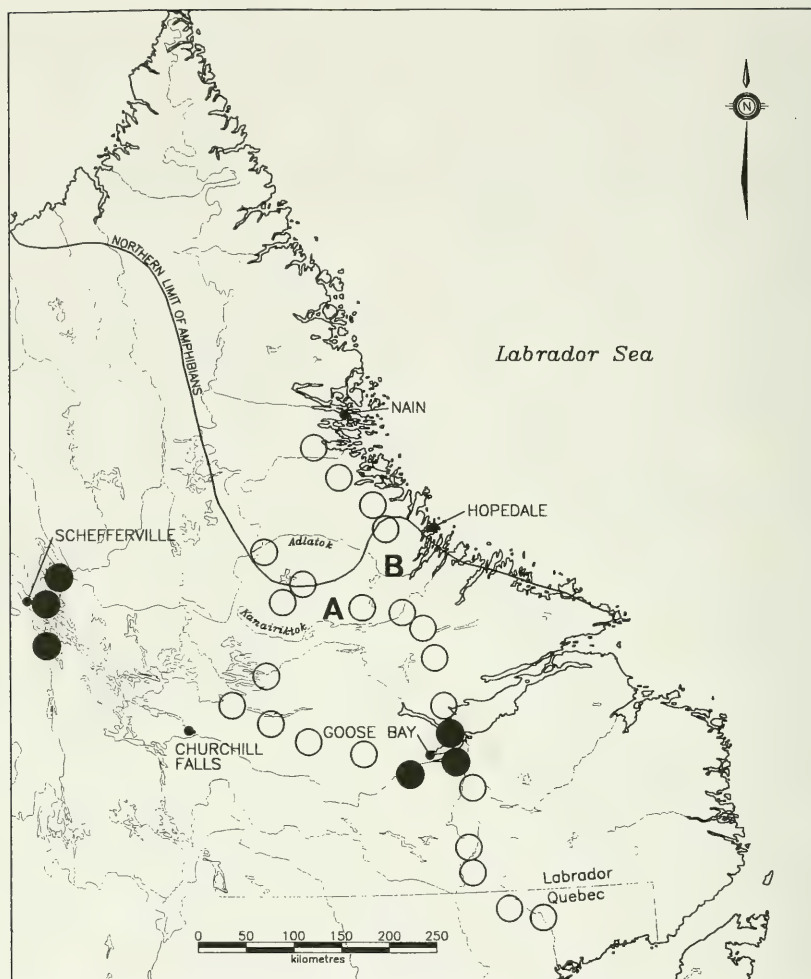


FIGURE 1. Distribution of the Wood Frog in Labrador. Darkened circles show locations described by Maunder (1983). Open circles show search areas with A and B indicating confirmed sightings on the Kanairiktok and Adlatok rivers respectively. Northern limit of Amphibians after Maunder (1983).

lated populations along the northern edge of the mid-subarctic forest ecoregion. As indicated by Maunder (1997), further study is required to precisely determine the distribution of amphibians in Labrador.

Acknowledgments

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Limited, Goose Bay Base for their exceptional helicopter support.

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An Extension of the Known Range of the Long-toed Salamander, *Ambystoma macrodactylum*, in Alberta

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Walsh, Robin. 1998. An extension of the known range of the Long-toed Salamander, *Ambystoma macrodactylum*, in Alberta. Canadian Field-Naturalist 112(2): 331–333.

Small populations of Long-toed Salamanders are reported from 55° 56' N, 118° 23' W near Fairview, Alberta. This is a significant extension of the range 300 km north in Alberta, and 125 km east of previous records in British Columbia. The new records are in aspen parkland, habitat from which these salamanders have not been previously reported in Alberta.

Key Words: Long-toed Salamander, *Ambystoma macrodactylum*, range extension, abundance, Peace River area, Alberta.

In Alberta, the Long-toed Salamander (*Ambystoma macrodactylum*) has been reported in montane, alpine, and subalpine areas from the Montana border north through Jasper National Park (Russell and Bauer 1993). The most northern location (approximately 54°20' N, 120° W) indicated on the range map published by Russell and Bauer (1993) apparently is an unsubstantiated report (Oseen et al. 1995*). The range map in Stebbins (1985) places the eastern portion of Long-toed Salamander distribution throughout the mountain ranges lying along the Alberta–British Columbia border and then following these ranges northwestward into British Columbia.

In 1993, a population was discovered in the Peace River region of Alberta near Fairview at 55° 56' N, 118° 23' W (Figure 1). In 1996, a search for more breeding ponds was conducted. Locations of ponds searched and the nine new populations found are shown in Figure 2. Adults have been annually first observed from mid April to late May, with eggs observed later. Larvae are most readily seen from late June to the middle of August. Most of the discovered populations are concentrated in an area 15 km south of the town of Fairview, with the exception of two, one that is 45 km to the northwest and another that is 10 km to the east (Figure 2). These records extend the known range in Alberta approximately 300 km north from the closest substantiated site, in the Hinton area at 53° 17' N, 117° 45' W (W. A. Hunt personal communication to Francis R. Cook, 1990; Russell and Bauer 1993; Oseen et al. 1995) and by 125 km east from the closest population reported in Green and Campbell (1984), near the



FIGURE 1. Known localities (black dots) for *Ambystoma macrodactylum* in Alberta and northeastern British Columbia (modified from Russell and Bauer 1993). Localities mentioned in the text are shown as open circles. In addition, the unlabelled open circle between (and east of) Waterton and Hinton shows the location of Calgary and the open star east of Hinton the location of Edmonton.



FIGURE 2. Ponds Searched: ● Salamanders found; ■ Salamanders not found; * Studied population

confluence of the Peace and Beaton rivers in British Columbia.

The newly discovered Peace River populations are at an elevation of approximately 500 m and are found within the relictual aspen parkland typical of the upper Peace Valley (Russell and Bauer 1993), 200 km from the mountains, unlike the previously reported *Ambystoma macrodactylum* habitat in Alberta (Russell and Bauer 1993). The area near Fairview averages 45 cm annual precipitation and 119 frost free days. A voucher specimen from this locality has been placed in the University of Alberta Vertebrate Zoology museum (UAVZ 3000).

All the ponds in which these salamanders have been found are adjacent to steep-sided ravines (up to 200 m deep) draining to the Peace River, and all are within 4 km of the Peace River itself. Most ponds are due to anthropogenic ("man"-made) dams created for water storage on spring runoff channels. The water ranges from relatively clear to extremely muddy due to cattle use. Surrounding plant communities mostly are Aspen Poplar (*Populus tremuloides*) forest, with the exception of two ponds surrounded by pasture land. Other amphibians present in the same ponds are the Wood Frog (*Rana sylvatica*) and the Striped Chorus Frog (*Pseudacris triseriata maculata*). The Red-Sided Garter Snake

(*Thamnophis sirtalis parietalis*) and the Wandering Garter Snake (*Thamnophis elegans vagrans*) have also been observed in the vicinity of some of the salamander ponds. The Western Toad (*Bufo boreas boreas*) has been observed near the Peace River in this general area.

The salamanders have an uninterrupted yellow-green dorsal stripe that exhibits irregular borders with deep undulations. This stripe begins at the snout and continues to the tip of the tail, and contains a variable number of irregular spots of ground color (black) throughout the stripe. Small white flecks (guanophores) are apparent on the sides and legs. In 1996, 79 adults were measured from one population (location shown on Figure 2). The average adult total length was 12.7 cm, with a standard deviation of ± 0.70 cm. The average total length of 60 males was 12.7 cm with a range of 11.1-14.5 cm and a standard deviation of ± 0.76 cm. The 19 females averaged 12.5 cm in total length, with a range of 11.5-13.4 cm and a standard deviation of ± 0.50 cm. The average snout-vent length was 6.1 cm for males (range of 5.6-6.9 cm), and 6.3 cm for females (range of 6.1-6.7 cm).

In her study near Waterton, Alberta, Fukumoto (1995) reported an average adult total length of 13.1 cm, with a range of 9.8-16.1 cm. The average

total length of males was 13.1 cm. The females averaged 13.0 cm in total length. The average snout-vent length was 6.4 cm for males (range of 5.5-7.0 cm), and 6.7 cm for females (range of 5.5-8.5 cm). Sheppard (1977) reported a range of adult total length of 8.0-12.0 cm in a population near Canmore, Alberta.

The Peace River area now is mainly agricultural. In the past, natural ponds were common, now almost all have been drained. Virtually the only suitable salamander habitat found to date exists in anthropogenic ponds, some of which are at risk of eroding into the ravines adjacent to them. Research into local distribution in the area is continuing.

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Attempted Predation on a Snowshoe Hare, *Lepus americanus*, by an American Marten, *Martes americana*, and a Northern Raven, *Corvus corax*

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Otto, Robert D. 1998. Attempted predation on a Snowshoe Hare, *Lepus americanus*, by an American Marten, *Martes americana*, and a Northern Raven, *Corvus corax*. Canadian Field-Naturalist 112(2): 333-334.

An individual Snowshoe Hare (*Lepus americanus*), observed to evade capture by an American Marten (*Martes americana*), was subsequently attacked by a Northern Raven (*Corvus corax*). To my knowledge, this represents the first observation of attempted predation on an apparently healthy Snowshoe Hare by a Northern Raven.

Key Words: Snowshoe Hare, *Lepus americanus*, Northern Raven, *Corvus corax*, American Marten, *Martes americana*, attempted predation, New Brunswick.

The Northern Raven (*Corvus corax*) is found throughout Canada with the exception of the high arctic and the prairie region of Manitoba, Saskatchewan, and Alberta (Godfrey 1986). They are predominantly carrion eaters, feeding on carcasses of mammals and fish, but are known to take a wide variety of food items, including rodents, nesting birds and eggs, insects, seeds, berries, and grains (Bent 1964). There are observations of ravens killing other birds including ptarmigan and puffins (emerging from burrows) in Greenland as well as partridge in Tibet (Madge and Burn 1994). American Marten (*Martes americana*) are known to feed on a wide variety of prey items including various small mammals, squirrels, hares, pikas, grouse, and other smaller birds (Banfield 1977).

The observations described were made while conducting research on wildlife communities in the north-central highlands of New Brunswick (Otto 1996), near the Little Southwest Miramichi River (47°10' N, 66°54' W) between 09:00 and 11:00 AST, 9 May 1994. While travelling by vehicle south over a small rise on a logging road, I noticed two shapes on the road approximately 200-300 m ahead. As I moved closer, I realised I was watching a marten and a Snowshoe Hare (*Lepus americanus*). The hare was moving away, but the marten was running toward my position (northward) and continued to do so until, at a distance of approximately 20 m, it reversed direction. During the entire time, the marten did not run in a straight line, but proceeded in a "zig-zag" pattern, keeping on the road at all

times. It appeared to be searching. The hare stayed on the road until the marten approached within 50 m, then hopped into the west ditch and remained motionless in short Balsam Fir (*Abies balsamea*) regeneration. This occurred approximately 300 m from initial sighting location. The marten did not detect the hare in the ditch as it ran past, and I followed the marten for a total of approximately 500 m when the marten turned into an area of manually thinned Balsam Fir and White Birch (*Betula papyrifera*) east of the road. The marten soon appeared behind my position (to the north) at an approximate distance of 30 m. I then noticed a Snowshoe Hare (presumably the same one initially sighted), coming toward me and the marten. The hare soon noticed the marten, and *vice versa*, and a short chase ensued. When the hare led the marten by approximately 50 m, the hare again hopped into a ditch (east) and remained motionless. The marten apparently did not see the hare run into the ditch, but obviously lost sight because it began to "zig-zag" back and forth across the road, presumably searching for a scent. The marten turned south toward me, approached within 30 m, and turned west into the forest. I did not observe the marten again. The hare waited for approximately 2 minutes, came out of the ditch, and proceeded north over a small crest in the road. I then observed a raven fly over the estimated position of the hare, suddenly turn, and dive toward the ground. I moved quickly forward and observed the hare and raven wrestling on the ground for approximately 10 seconds. The raven then disengaged from the hare and flew away. The hare hopped a short distance and sat under a

small Balsam Fir tree. I approached within 2 m of the hare and it did not move. No physical injuries were obvious, but it appeared somewhat disoriented and reluctant to move.

Although perhaps winded after escaping from the marten, the hare seemed healthy. It is not possible to determine the effectiveness of the attack because I believe my presence probably scared off the raven, although it is possible the raven realised it could not subdue the hare. The *principalis* subspecies (in this region) is one of the largest in the world and, based on other reported predations (Madge and Burn 1994), should be able to take prey as large as Snowshoe Hares. As far as I can determine, this is the first report of a raven attempting to kill a Snowshoe Hare.

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Increase in Populations of Henry's Elfin, *Callophrys henrici*, (Lepidoptera: Lycaenidae), in Ottawa-Carleton, Ontario, Associated with Man-made Habitats and Glossy Buckthorn, *Rhamnus frangula*, Thickets

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Catling, P. M., R. A. Layberry, J. P. Crolla, and P. W. Hall. 1998. Increase in populations of Henry's Elfin, *Callophrys henrici* (Lepidoptera: Lycaenidae) in Ottawa-Carleton, Ontario, associated with man-made habitats and Glossy Buckthorn, *Rhamnus frangula*, thickets. *Canadian Field-Naturalist* 112(2): 335-337.

Between 1980 and 1996, 32 occurrences of *Callophrys henrici* were discovered to the south and east of Ottawa in regions of sand, loam, peat and limestone on abandoned farmlands. The habitats ranged from openings in Glossy Buckthorn (*Rhamnus frangula*) thickets to openings and clearings in second growth woodland mostly of poplars (*Populus* spp.) and/or Cedar (*Thuja occidentalis*). In most cases the sites had been open farmlands, mostly pastures, 10-70 years ago. The new occurrences in man-made habitats are within a landscape that was largely unoccupied by *C. henrici* previously, and they represent a 7-fold increase in the number of occurrences in the local area, associated with a several-fold increase in suitable habitat. The association with Glossy Buckthorn was further established through successful rearing of larvae to normal adults. With the capability of using abandoned farmlands, and the continuing spread of the introduced Glossy Buckthorn, the previously uncommon and local *C. henrici* may become a much more common butterfly in Ontario over the next few decades.

Key Words: Henry's Elfin, *Callophrys henrici*, Glossy Buckthorn, *Rhamnus frangula*, foodplant, alien, ecology, life history, Ontario.

In Ontario Henry's Elfin, *Callophrys henrici* Grote and Robinson, has been considered an uncommon and very local species associated with bog fringe forest (Mer Bleue, Alfred), Oak-Pine savanna scrub on sandy soils (St. Williams, Centreton, Constance Bay), and rock barrens of the southern Canadian Shield (Perth Road, Chaffey's Locks, Kaladar). In these natural habitats, blueberries (*Vaccinium* spp.) have been reported as the larval foodplant (e.g., Holmes et al. 1991), and both *Vaccinium* spp. and *Prunus* spp. have been reported as larval hosts elsewhere in the range (e.g., Scott 1986). Henry's Elfin was given an S3 ranking in Ontario denoting between 20 and 100 occurrences in the province (Holmes et al. 1991), and it has also been considered rare and local in some adjacent regions. Shapiro (1974), for example, noted that it was "one of the least known New York butterflies".

Among the insects, butterflies have been relatively well studied and many regional lists and yearly summaries are available (e.g., Toronto Entomologists' Association, Lepidopterists' Society, Holmes et al. 1991). Consequently changes in status and distribution are likely to be quickly detected. A change in the status of *C. henrici* was first noticed in 1980 when R. A. Layberry found a colony of *C. henrici* on abandoned farmland south of Leitrim (45°20'N, 75°36'W), Ontario (Hess 1981). Later (Layberry 1988) he reported finding eggs at this location on the

invading alien shrub, Glossy Buckthorn (*Rhamnus frangula* L.), and he found both eggs and larvae on Glossy Buckthorn at a nearby location. He reared the larvae to pupal stage on this shrub, but the pupae died. Hall and Layberry (1988) reported an increase in the number of colonies of *C. henrici* in the Ottawa district and speculated that Glossy Buckthorn may be the most widely used foodplant in the area because it was common where the butterflies occurred. More recently Glassberg (1993) noted that use of Glossy Buckthorn as a foodplant had resulted in more diverse habitats and an increase in the population of *C. henrici* in the Boston area. Here we provide additional information on the increase in populations of Henry's Elfin associated with man-made habitats and Glossy Buckthorn thickets in the Ottawa region of eastern Ontario.

Man-made versus Natural Habitats

Natural habitats in Ottawa-Carleton are representative of Ontario habitats in general including oak-pine savanna on sand at Constance Bay (Figure 1, number 1), bog fringe forest at Mer Bleue (Figure 1 number 2), and open scrubby areas associated with granite and sandstone exposures west and southwest of Ottawa (Figure 1). In all of these locations Blueberries (*Vaccinium angustifolium* Aiton and/or *V. corymbosum* L.) as well as *Prunus* ssp. are frequent, and the natural habitats have probably existed

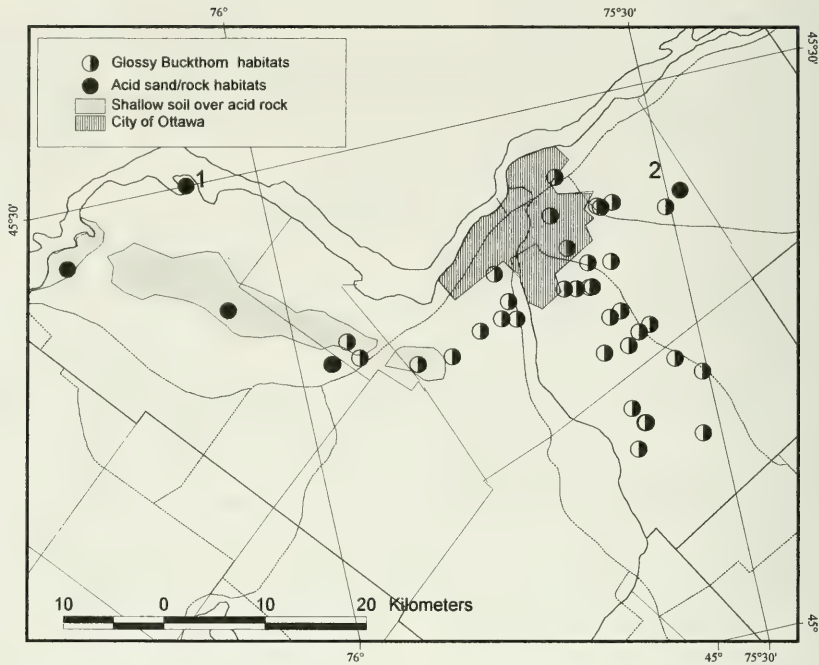


FIGURE 1. Portion of the Regional Municipality of Ottawa-Carleton, Ontario, showing occurrences of *Callophrys henrici* in natural habitats (dots) and in abandoned farmland associated with Glossy Buckthorn (half dots). 1 = long known colony at Constance Bay in Oak-Pine savanna; 2 = natural habitat along forested edges of Mer Bleue bog. The shaded area west of the city (vertical hatching) represents areas of natural openings over acid granite or sandstone rocks.

for hundreds of years. At least five occurrences (locations where a butterfly was seen separated by at least 1 km from another observation point) are known from these natural habitats.

Between 1980 and 1996, 32 occurrences were discovered to the south and east of the city in regions of sand, loam, peat and limestone on abandoned farmlands. The habitats ranged from openings in Glossy Buckthorn thickets to openings and clearings in second growth woodland mostly of poplars (*Populus* spp.) and/or Cedar (*Thuja occidentalis* L.). Thirty of the sites had been open farmlands, mostly pastures 10–70 years ago, and two were drained wetlands. Consequently they are new occurrences in man-made habitats, but in addition they are within a landscape that was largely unoccupied by *C. henrici* previously, and they have resulted in a 7-fold increase in the number of occurrences in Ottawa-Carleton.

Association with Glossy Buckthorn

At each of the man-made habitats, Glossy Buckthorn is present, and in most cases it is a dominant in the vegetation cover. The abandoned farmlands south of Ottawa are a region of major infestation of Glossy Buckthorn (Catling and Porebski 1994). The plant invaded the area during the 1940s

and had become dominant on many parts of the landscape by the 1990s (Catling and Porebski 1994).

Four females from abandoned farmlands near Leitrim laid eggs on Glossy Buckthorn in captivity from 23–25 May 1996. The eggs were laid mostly singly on branches 1–2 years old and most often in leaf axils or near buds. From these eggs 20 larvae emerged. These were reared to adults of normal size and appearance on Glossy Buckthorn over a period of 35–40 days at 75–85°F under constant light. All of the larvae emerged as adults from 4–7 July 1996. Some of the reared adults were deposited in the Canadian National Collection maintained by Agriculture and Agri-food Canada in Ottawa. This successful rearing on Glossy Buckthorn, as well as association with the shrub at 32 locations, further establishes the relationship based on finding of eggs and larvae on the shrub (Layberry 1988) and on the circumstantial evidence (Hall and Layberry 1988).

To the extent that the introduced Glossy Buckthorn is spreading (Catling and Porebski 1994), and marginal farmlands continue to be abandoned near urban areas, it is anticipated that *C. henrici* may become a much more common butterfly in Ontario over the next few decades. It is estimated that the area of suitable habitat in the Ontario portion of the

Ottawa district has increased by several times (Figure 1) due to invasion of Glossy Buckthorn. In addition to the spread into abandoned farmlands south of Ottawa, three occurrences of *C. henrici* were discovered in a similar habitat with an abundance of invading Glossy Buckthorn near Maitland (44°38'N, 75°37'W, Leeds and Grenville County) Ontario. Of course the use of man-made habitats and introduced foodplants by native butterflies is not unusual, but the previously uncommon and local status of *C. henrici*, and the serious damage to native habitats resulting from invasion of Glossy Buckthorn make this a particularly interesting relationship.

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Additions à la flore native de Saint-Pierre et Miquelon

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B.P. 328 Saint-Pierre, îles Saint-Pierre et Miquelon

Etcheberry, Roger. 1998. Additions à la flore native de Saint-Pierre et Miquelon. *Canadian Field-Naturalist* 112(2) : 337–339.

Une population d'Ophioglosse vulgaire (*Ophioglossum vulgatum*) Ophioglossacées, fut découverte pour la première fois aux îles Saint-Pierre et Miquelon. Cette population étend l'aire de répartition de l'espèce considérablement vers l'Est, l'espèce étant inconnue au Cap Breton et à Terre-Neuve. Une autre nouvelle espèce d'Ophioglossacées, *Botrychium multifidum* a été également découverte dans la même zone.

Mot clés : Ophioglosse vulgaire, *Ophioglossum vulgatum*, St-Pierre et Miquelon.

A population of Adder's tongue (*Ophioglossum vulgatum*) Ophioglossaceae, was found for the first time in the islands of Saint-Pierre et Miquelon. This population represents a significant range extension for a species not known on Cap Breton island nor on insular Newfoundland. Another species of Ophioglossaceae, *Botrychium multifidum* was also found in the same area.

Key Words : Adder's tongue, *Ophioglossum vulgatum*, St-Pierre et Miquelon.

La flore de St-Pierre et Miquelon comprend 637 espèces de plantes vasculaires dont 515 sont considérées comme indigènes et 122 comme introduites (Le Gallo 1954). Treize nouvelles espèces natives ont été ajoutées récemment (Rouleau et Lamoureux 1992).

Durant l'été de 1996 une population d'Ophioglosse vulgaire (*Ophioglossum vulgatum*) Ophioglossacées, a été découverte dans la partie Sud de l'Isthme de Langlade ca 46°55'N et 56°19'50". Cette population représente une extension significative de l'aire de répartition connue de l'espèce de plus de 600 kilomètres.

La distribution d'*Ophioglossum vulgatum* est circumpolaire, le var. *pseudopodium* pousse, dans l'Est

du continent, en Nouvelle Écosse et jusqu'en Ontario (Cody et Britton 1989). La plante n'est pas connue de Terre-Neuve (Rouleau et Lamoureux 1992); les cartes de distribution de A. E. Rolland (1944/45) pour la Nouvelle Écosse, et de Catling et al. (1985) pour l'île du Prince Edouard ne la mentionne pas à l'ouest du 63ème méridien. L'espèce n'est pas mentionnée pour l'île des sables (Catling et al. 1984) qui possède des habitats similaires à ceux de l'Isthme de Langlade.

La population occupe une dépression relativement humide, de plusieurs centaines de m², souvent inondée au printemps, assez bien délimitée par *Juncus balticus*, entre deux dunes côtières. La dis-

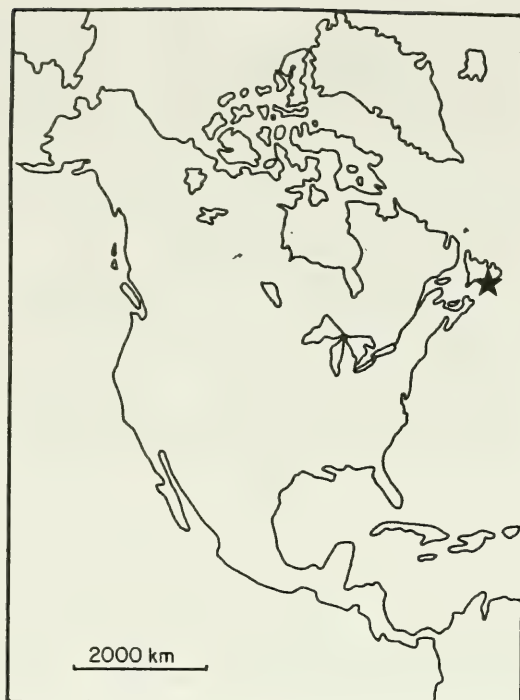


FIGURE 1. Position géographique des îles St-Pierre et Miquelon en Amérique du Nord;

tance totale entre les côtes Est et Ouest de l'Isthme à cet endroit varie entre 250 et 500 mètres.

La strate muscinale importante est surtout constituée de *Drepanocladus uncinatus*. Les espèces de plantes vasculaires suivantes ont été notées dans les abords immédiats: *Potentilla anserina*, *Sisyrinchium angustifolium*, *Vaccinium macrocarpon*, *Juncus balticus*, *Halenia deflexa*, *Euphrasia randii*, *E. americana*, *Carex nigra*, *C. paleacea*, *Spiranthes romanzoffiana*, *Platanthera psychodes*, *Leontodon autumnalis*, *Smilacina stellata*, *Trifolium repens*, *T. pratense*, *Drosera rotundifolia* et *Alnus crispa* (rare).

Au moment de la découverte, le 13 août 1996, elle était nettement fructifiée et la production de spores était abondante. Des recherches dans les environs et dans d'autres habitats similaires ont été faites, sans résultats. Elle devra être recherchée dans l'île de Terre-Neuve. Comme indiqué dans la plupart des ouvrages, elle passe très facilement inaperçue.

Au cours des mêmes recherches, une minuscule station, d'une douzaine d'individus, d'un autre *Ophioglossacée*: *Botrychium multifidum* (Gmel.) Rupr. à été découverte en terrain plus sec et pauvre à quelques centaines de mètres au Sud-Est de la précédente. C'est également une nouvelle espèce pour l'Archipel de Saint-Pierre et Miquelon. L'espèce est peu commune à Terre-Neuve sur la côte Ouest; un seul site est mentionné pour la côte Sud et deux pour

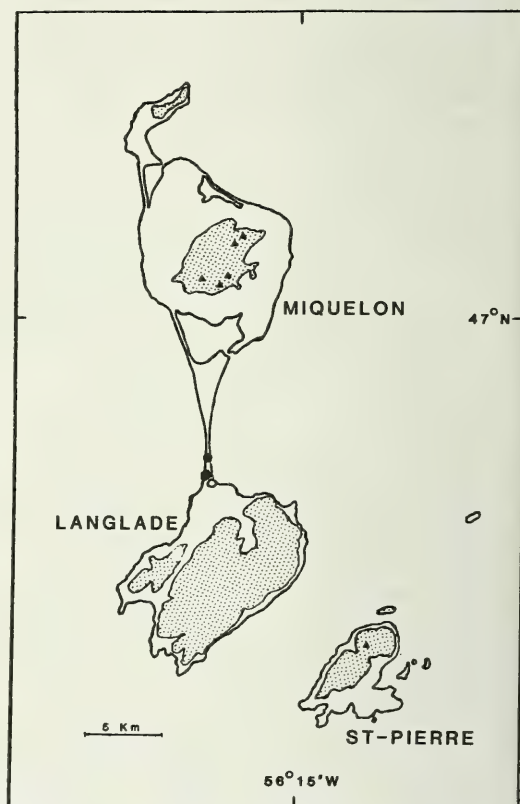
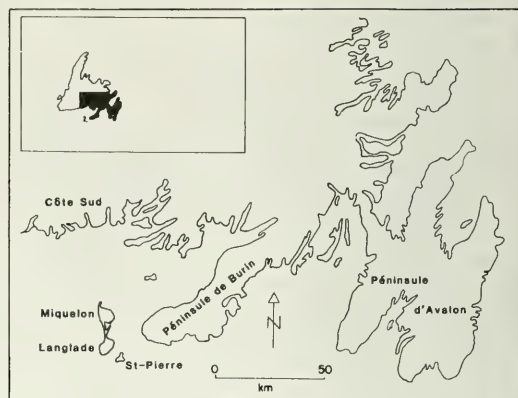


FIGURE 2. Topographie des îles St-Pierre et Miquelon. *Ophioglossum vulgatum*, *Botrychium multifidum*. Les régions en pointillé ont une altitude supérieure à 100 m. Les triangles représentent les sommets de plus de 200 m.

la péninsule d'Avalon (Rouleau et Lamoureux (1992).

Des spécimens de *O. vulgatum* et de *Botrychium multifidum* ont été déposés à l'herbier Marie-Victorin (MT : Roger Etcheberry n° 1525 et 1526 respectivement).

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Low Cooper's Hawk, *Accipiter cooperii*, Nest in Dense Shrubs

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Sondreal, Marriah L., and Robert K. Murphy. 1998. Low Cooper's Hawk, *Accipiter cooperii*, nest in dense shrubs. Canadian Field-Naturalist 112(2): 339–340.

A pair of Cooper's Hawks (*Accipiter cooperii*) successfully fledged young from an unusually low nest in dense shrubs in northwestern North Dakota.

Key Words: Cooper's Hawk, *Accipiter cooperii*, nesting, shrubs, North Dakota.

Cooper's Hawks (*Accipiter cooperii*) typically nest about 5–15 m above ground within or just beneath dense tree canopies (Palmer 1988; Rosenfield and Bielefeldt 1993). Herein, we describe an unusually low, densely vegetated nest site that was used successfully by Cooper's Hawks at Lostwood National Wildlife Refuge in northwestern North Dakota (48°39'N, 102°23'W). In our description of nest site habitat, shrubs are distinguished as woody plant species from trees by having several basal shoots instead of a single bole, a broad growth habit instead of crown shape, and maximum height seldom exceeding 5 m (Jacoby 1989). Thus, we consider mature Northern Hawthorn (*Crataegus rotundifolia*) and Choke Cherry (*Prunus virginiana*) as shrubs and mature Quaking Aspen (*Populus tremuloides*) as a tree.

On 16 July 1994, we flushed an adult Cooper's Hawk from a stick nest in a Northern Hawthorn, centered within approximately 30 × 100 m of 2–4 m tall, dense shrubs. The nest contained three young about 15–17 days old. Three young remained when we returned 20 July, and we subsequently observed two fledged young within 100 m of the nest through late August.

The nest, 41 cm deep and 28 cm wide, was located 2.1 m high (top of nest rim) in a 3.7-m tall hawthorn. The nest comprised primarily Quaking

Aspen and Choke Cherry twigs. Twelve branches supported the nest 25 cm above a main fork in a shrub stem. Diameter of the stem supporting the nest was 11 cm at ground level and 7 cm at 1.5 m above ground. About 80% of the shrub canopy above and within 1 m (horizontal) of the nest was closed (i.e., shaded); there was no opening more than 22 cm wide for adult hawks to access the nest. Within 12 m of the nest there was almost continuous shrub canopy consisting of 35% hawthorn, 50% Choke Cherry, and 10% other shrub species. Shrub stem density (James and Shugart 1970) at the nest site was 134 615 stems/ha, such that it was difficult to see a person standing 5 m away.

Annually during 1987–1990, a pair of Cooper's Hawks nested in a 0.8-ha patch of Quaking Aspen trees adjacent to the shrub clump used in 1994. The hawks failed to fledge young in each of those years. Causes of nest failure were unknown except in 1989, when a brood of four young were depredated by a Great Horned Owl (*Bubo virginianus*) when about 24 days old (RKM, unpublished data). During 1991–1993, 75% of above-ground growth of the aspen died due to severe drought; the area was not checked for occupancy by nesting Cooper's Hawks during these years. The nest in shrub habitat we noted was the first successful nesting in the area in

five known attempts, suggesting that the site afforded greater protection against predators such as Great Horned Owls than had nearby aspen trees.

In the arid southwestern United States, Cooper's Hawks sometimes nest at heights of 3–5 m in small trees (Millsap 1981; M. Siders, N. Kaibab Ranger District, USDA Forest Service, personal communication). However, we know of no published records of nest placement as low as 2 m, and none of shrub-nesting by the hawk in central or eastern North America. Bendire (1892: 193) may have implied shrub-nesting occurs in the Great Plains: "[Cooper's Hawks] . . . are confined to the shrubbery of the creek bottoms, consisting mainly of cottonwoods [presumably *P. deltoides*] and willows [*Salix* spp.], they sometimes nest as low as 10 feet [3.1 m] from the ground. . ." Regardless, our observation indicates that resource management personnel should consider tall shrub habitat as potential nest sites for Cooper's Hawks in the northern Great Plains.

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while MLS was a wildlife intern under auspices of the College of Natural Resources, University of Wisconsin-Stevens Point.

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Tolerance by Denning Wolves, *Canis lupus*, to Human Disturbance

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Thiel, Richard P., Samuel Merrill, and L. David Mech. 1998. Tolerance by denning Wolves, *Canis lupus*, to human disturbance. Canadian Field-Naturalist. 112(2): 340–342.

Wolves are considered to be intolerant of human activity, especially near dens and pups. In recent years range extensions of the species in the upper Great Lakes region have brought Wolves in closer contact with humans. We report observations of Wolves tolerating human activity in close proximity to dens and rendezvous sites with pups. These include moss harvesting work in the Black River State Forest, Wisconsin; military maneuvers at Camp Ripley Military Reservation, and road construction work in the Superior National Forest in Minnesota.

Key Words: Gray Wolf, *Canis lupus*, dens, pups, human activity, tolerance.

Until recently, the Gray Wolf (*Canis lupus*) survived primarily in wilderness areas, and came to be seen as a symbol of the wilderness (Theberge 1975). The main reason for this was that Wolves had been persecuted and exterminated in all nonwilderness areas (Young and Goldman 1944; Mech 1995). However, during the past two decades, Wolves have been returning to many areas where they have not

lived for many years (Mech 1995). As they have done so, they have been adapting to human activities and disturbances. For example, they have crossed large expanses of nonforested areas (Licht and Fritts 1994) and even four-lane highways (Mech et al. 1995). In Europe, they enter villages at night to seek garbage (Zimen and Boitani 1975), and in North America, they frequent the outskirts of

villages, sometimes killing dogs (Fritts and Paul 1989).

When Wolves lived only in wilderness, they were thought to have a low tolerance for human disturbance near their dens and pups, and this may be true in wilderness settings. For example, in open tundra of northern Alaska, Wolves seemed to be intolerant of humans approaching to less than 0.8 km (Chapman 1979). However, when protected from human exploitation, for example in Denali National Park, Alaska, Wolves sometimes tolerate humans close to dens and pups. In 1988, an East Fork pack female during a natural move, carried her pups one by one down the park road several km from one den to another. In 1989, another female kept her pups for ≥ 27 days within 100 m of this road and tolerated humans taking close-up pictures of her pups (Mech et al. 1998).

As Wolf populations recover in areas of higher human activity, land and resource managers are faced with whether or not to place land-use restrictions in areas where Wolves are recovering. One commonly proposed restriction is prohibiting various types of human activity within certain distances of Wolf den and rendezvous sites. For example, Denali National Park maintains closures around Wolf dens and rendezvous sites, including some rendezvous sites that have not been used in many years (L. D. Mech, T. J. Meier, J. W. Burch, unpublished). Regulations governing Wolf reintroductions in Yellowstone National Park allow closing areas to human visitation for 1.6 km around active dens from 15 March to 1 July (Fritts et al. 1994). The Wisconsin Department of Natural Resources recommends closing areas within 100 m of dens and restricting use from 100 to 800 m from dens from 1 March to 31 July (Wydeven and Schultz. 1992. Management policy for wolf den and rendezvous sites. Unpublished Report. Wisconsin Department of Natural Resources. 11 pages).

However, land-use restrictions are highly controversial and are opposed by many local residents more than the restoration of Wolves itself (Tucker and Pletscher 1989; Thiel and Valen 1995). Thus it is important to document the degree of adaptability of Wolves to human activity around dens and pups. We report on recent anecdotal observations of tolerance displayed by Wolves towards humans in proximity to dens and pups.

Wolves became established in west-central Wisconsin in the early 1990s. The Wildcat pack denned at a contract-operated sphagnum-moss drying bed site in the Black River State Forest in 1993, 1994 and 1995. The den is located within 0.8 km of an intensively utilized ATV trail, and within 2 km of Interstate Highway 94.

The 1993 and 1994 den entrance was located on the edge of the drying bed. Early during the 1994 denning season (early April to mid May), sometime after the litter was believed to have been born, the

bed was bladed free of vegetation to prepare the site for drying moss. In the process the entrance was buried. The Wolves moved 150 m into the forest and dug a new den. Despite this level of disturbance, the Wolves re-excavated the site in winter 1994-95 (Thiel et al. 1997) and raised a litter there in 1995.

Over a two-week period in 1995 the moss pullers daily parked their trucks within 100 m of the den, and frequently observed Wolves. On most occasions the Wolves appeared unconcerned by the people's presence. Once a Wolf walked past a parked truck, and on another occasion a Wolf sat down on a hillside and watched the men pulling moss in the marsh. On one occasion the men heard a Wolf barking. In late April the Forest Superintendent was apprised of the men's presence at the den site, and the activity was temporarily suspended.

In Montana, a pack of Wolves kept its pups in a rendezvous site 0.8 km from a helicopter logging operation during summer 1994. Helicopters lifted 6500 tons of logs from the cutting over a 3-month period while the Wolves occupied the site (Jimenez 1995).

Wolves breeding on Camp Ripley Military Reservation in Minnesota demonstrate a high level of resilience during the breeding season (Merrill 1996). Camp Ripley trains nearly 40000 troops annually, primarily during summer. Most of these activities are concentrated in the Wolves' territory. This has resulted in numerous encounters between Wolves and humans involving vehicles as well as sounds from artillery, and shells exploding in impact zones.

In late July 1995 the alpha pair and their four pups used a rendezvous site in a sand-pit that was surrounded by a battalion of troops in training. About 300 soldiers and 100 large military vehicles were located within 0.5 km of the pack. At any one time, roughly 20 vehicles were running, and it was impossible not to hear their engines and the yelling of troops. At one point a group of soldiers and five large armored vehicles set up an ambush station in the sand-pit. The Wolves retreated 50 m into the woods.

One of the pack's rendezvous sites was inside an artillery impact site. Though this area was devoid of human activity, the Wolves were 0.2 to 1.9 km from several target locations for high explosive rocket and rifle fire. A similar situation occurred when numerous heavy artillery howitzers were engaging in live-fire exercises within 0.3 km of the Wolves.

In 1996 the alpha pair at Camp Ripley produced another six pups. Three rendezvous sites were found between July and September, and two of them were on the edges of active firing ranges. In July, troops reported seeing adults and pups in a culvert less than 100 m from active tank firing stations. After several days the adults were observed moving the pups off the range. A few days later the next rendezvous site

was found 500 m away in a different part of the same firing range.

Since 1995, one or more Wolves have frequently been observed crossing or standing on a road and sometimes do not move until a vehicle approaches within 10 m. After three years of relatively close contact with human activity, the Ripley Wolves have become less fearful of humans than wild Wolves are normally thought to be.

In northeastern Minnesota, where wolves were legally protected in 1974, some packs are also becoming highly tolerant of human disturbance. A pack of at least three adults and five pups occupied a rendezvous site from at least 15 July to 15 August, 1997 within 100 m of an active gravel pit, where a noisy stone crusher operated day and night, and where large trucks and bull dozers worked daily. At night both pups and adults frequented the pit itself.

These observations indicate the degree of tolerance some Wolves display towards humans close to their dens and offspring, and how easily they can habituate to human caused disturbances. While it is true that Wolves may move their pups in response to human disturbances, our observations suggest that Wolves do not move pups long distances, and as Ballard et al. (1987) observed, pup survival is not decreased by these disturbances.

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Unusual Eye Vibrissae on a White-tailed Deer, *Odocoileus virginianus*, and other Pelage Anomalies from Upper Michigan

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Seymour, Donald L., and Timothy R. Van Deelen. 1998. Unusual eye vibrissae on a White-tailed Deer, *Odocoileus virginianus*, and other pelage anomalies from upper Michigan. *Canadian Field-Naturalist* 112(2): 343.

We report a White-tailed Deer that had unusually long vibrissae (maximum = 16.0 cm) surrounding its eyes. This pelage anomaly has apparently not been previously documented.

Key Words: White-tailed Deer, *Odocoileus virginianus*, vibrissae, pelage, Michigan.

During December 1996, the senior author shot a male White-tailed Deer, *Odocoileus virginianus*, in the central portion of the Upper Peninsula of Michigan with unusually long vibrissae surrounding both eyes. Over the left eye were 21 vibrissae ≥ 5.0 cm (\bar{x} = SD = 2.5, Range: 5.0 to 13.0 cm) whereas over the left eye were 25 vibrissae ≥ 5.0 cm (\bar{x} = 8.0, SD = 2.9, Range: 5.0 to 16.0 cm). This deer was aged at 1.5 years according to tooth wear/replacement (Severinghaus 1949) and its dressed weight was approximately 45 kg. The deer's antlers were small polished "buttons" more characteristic of male deer in the fawn age class (0.5 years). Upon superficial examination the deer appeared otherwise normal. At least seven other deer (three males, four females, all adult) with relatively long (circa 6.0 cm) vibrissae were encountered during a trap-tag-release study in adjacent Delta County in which 91 deer were handled (1996–1997 field season). However, none had vibrissae as long as those measured on the specimen described above.

Technical descriptions of White-tailed Deer pelage (i.e., Moen and Severinghaus 1984; Bubenik 1996) have not included specialized hair such as eyelashes and vibrissae and most pelage anomalies reported for White-tailed Deer concern color aberrations. Sauer (1984) listed three pelage anomalies occurring in White-tailed Deer, all concerning coloration: (1) albinism characterized by white pelage and pink eyes resulting from an absence of the pigment melanin, (2) melanism characterized by an unusually dark coat resulting from excess melanin, and (3) the piebald condition resulting from an overrepresentation of normally occurring white hairs. Although the piebald condition is the most frequently seen, these conditions are uncommon, occurring in < 1% of hunted populations (Smith et al. 1984). In a survey of anomalies reported for deer harvested in Michigan from 1953 to 1961, Ryel (1963) reported 23 piebald and 2 albino deer out of 96 500 examined. Also seen were two deer with "manes" resulting from unusually long hair (15 cm) on the neck. Hair in the neck region is normally 4 to 6 cm (Moen

and Severinghaus 1984; Bubenik 1996). Melanism has not been reported for deer in Michigan (Ryel 1963; Baker 1984).

In this portion of the Upper Peninsula similar pelage anomalies are not unknown. During various research and management activities, we have captured deer with piebald characteristics that range from white feet to extensive white patches on the sides, flanks, and shoulders. Although albino deer are much rarer, the Michigan Department of Natural Resources (MDNR) has a mounted specimen from Delta County in the lobby of its Escanaba Field Office. Also, a deer was shot during 1996 that had no guard hairs (C. Albright, MDNR, personal communication). Apparently, pelage anomalies concerning the abnormal growth of hair are much more unusual or have not been previously documented.

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An Albino Snapping Turtle, *Chelydra serpentina*, from Québec

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A hatchling albino Snapping Turtle (*Chelydra serpentina*) was captured in Terrasse-Vaudreuil on Ile-Perrot, Québec. This is the first report of albinism in this species in Québec.

Key Words: Snapping Turtle, *Chelydra serpentina*, albinism, Québec.

Hensley (1959) documented two cases of albinism for the Snapping Turtle, *Chelydra serpentina*, one of which was from Canada and occurred near Windsor, Ontario. Judd (1971) reported another specimen from the vicinity of London, Ontario. Another specimen was photographed in 1981 in Point Pelee National Park in Essex County, Ontario (Oldham, personal communication). Five additional records for the United States were summarized in Dyrkacz (1981). Recently, Williams and Norden (1992) reported a specimen from Maryland. Here, we describe an additional instance of albinism from a northern population of Snapping Turtles.

On 14 September 1995, an albino hatchling Snapping Turtle (Figure 1) was collected as it exited from its nest, at approximately 16:00. Unfortunately, the clutch size and presence of other abnormally pigmented turtles was not recorded. The nesting site

was located in Terrasse-Vaudreuil on the northern most tip of Ile-Perrot, Québec (45°23'30"N, 73°58'00"W). The turtle had red eyes and white skin, but appeared slightly pink. On 25 September 1995, the specimen was measured with dial calipers and found to have a straight line carapace length and width of 30.0 mm and 28.4 mm, respectively. The turtle also had a plastron length of 19.7 mm and a mass of 7 g. It was maintained by the collector, Robert Lamoureux, until its death on 20 January 1996 and was subsequently deposited at the Royal Ontario Museum (ROM 29086).

Acknowledgments

We wish to thank Robert, Etienne, and Karine Lamoureux for bringing this turtle to our attention. We also thank Francis R. Cook, Michael J. Oldham of the Natural Heritage Information Centre, Ontario Ministry of Natural Resources in Peterborough, Ontario, and one anonymous reviewer for providing helpful suggestions to improve the manuscript.

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FIGURE 1. Albino hatchling *Chelydra serpentina* collected on Ile-Perrot, Québec. Dark areas on posterior carapace are soil deposits (Photograph by D. Rodrigue on 24 September 1995).

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Identification of Northern Pocket Gopher, *Thomomys talpoides*, Remains in Long-tailed Weasel, *Mustela frenata longicauda*, Scats

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Proulx, Gilbert, and Pamela J. Cole. 1998. Identification of Northern Pocket Gopher, *Thomomys talpoides*, remains in Long-tailed Weasel, *Mustela frenata longicauda*, scats. Canadian Field-Naturalist 112(2): 345–346.

Nine Long-tailed Weasel (*Mustela frenata longicauda*) scats were collected on Northern Pocket Gopher (*Thomomys talpoides*) mounds in an alfalfa field in Gwynne, Alberta, from 21 to 29 September 1995. Northern Pocket Gopher remains were found exclusively in six (67%) scats. Deer Mouse (*Peromyscus maniculatus*) remains were identified in the three (33%) other scats. The pocket gopher mounds had been built between late July and September and thus our findings are a snapshot of Long-tailed Weasel feeding activities that occurred in late summer. However, they are the first confirmed cases of Northern Pocket Gopher remains in Long-tailed Weasel scats.

Key Words: Long-tailed Weasel, *Mustela frenata longicauda*, Northern Pocket Gopher, *Thomomys talpoides*, food habits, predator, prey, Alberta.

Pocket gopher (*Geomys* spp. and *Thomomys* spp.) burrow systems are inhabited by several terrestrial species (Vaughan 1961; Whittaker et al. 1991) that may be preyed upon by Long-tailed Weasels (*Mustela frenata longicauda*). In the past, Long-tailed Weasels have been observed in the burrows of pocket gophers (Polderboer et al. 1941; Florine 1942; Vaughan 1961) but there is little evidence that they prey upon them. Criddle and Criddle (1925) suggested that in winter Long-tailed Weasels entered burrow systems to kill the resident pocket gopher and other rodents. However, only once did they encounter a weasel carting a recently-killed pocket gopher. They also reported that Long-tailed Weasels fed on dead pocket gophers that they had placed near their laboratory. Hansen and Ward (1965) found partially eaten Northern Pocket Gophers (*Thomomys talpoides*) that had been killed in traps and, because Long-tailed Weasels had been captured in nearby traps, suggested a predator-prey relationship between these two species. However, such a relationship has never been ascertained by scat or stomach analyses. We report on an analysis of Long-tailed Weasel scats found on Northern Pocket Gopher mounds.

The collection of Long-tailed Weasel scats occurred from 21 to 29 September 1995 in an 8-ha portion of a 65-ha alfalfa field in Gwynne, approximately 100 km south of Edmonton, Alberta. Scats were identified according to Murie (1975), bagged and frozen. In August 1996, they were thawed and washed through a fine sieve. Identification of the remains was done according to Moore et al. (1994) and by comparison with museum specimens.

Nine Long-tailed Weasel scats were collected on Northern Pocket Gopher mounds ≤ 100 m from each other and from the alfalfa field edge that was adjacent to a woodlot. Four of these scats were found on the same mound. Northern Pocket Gopher remains were found exclusively in six (67%) out of nine

scats. In two cases, bone fragments were used to confirm the identification based on hair scale impressions. Deer Mouse (*Peromyscus maniculatus*) remains (hair, bone fragments and teeth) were identified in three (33%) other scats.

Considering that all the scats were close to each other, it is likely that they represent the food habits of only one Long-tailed Weasel (Svendsen 1982; King 1989). Because all the pocket gopher mounds had been destroyed during the mid-July hay harvest, these scats were deposited on mounds that were built between late July and late September. Therefore, our findings are a snapshot of Long-tailed Weasel feeding activities that occurred in late summer. At this time of year, juvenile pocket gophers are dispersing (Proulx 1997) and busy excavating their burrow system (Proulx et al. 1995) and they may be more vulnerable to Long-tailed Weasel predation. Indeed, small mammal studies (e.g., Jerdzewska 1989) have indicated that transient animals are more susceptible to weasel predation than residents.

To our knowledge, our study is the first to report Northern Pocket Gopher remains in Long-tailed Weasel scats. During the week preceding the collection of these scats, a pocket gopher kill-trapping program had been carried out at the centre of the field. None of the killed pocket gophers showed signs of scavenging and the discarded carcasses were still untouched during the week that we collected Long-tailed Weasel scats. Therefore, we do not believe that the presence of pocket gopher in weasel scats is the result of scavenging. This study and Proulx and Drescher's (1993) suggestion that the distribution of Long-tailed Weasel in Alberta may be intimately related with that of the Northern Pocket Gopher warrant more research to explain better the relationship existing between these two species.

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Moulting Sites of Sea Ducks and other Marine Birds in Frederick Sound, Southeast Alaska

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Butler, Robert W. 1998. Moulting sites of sea ducks and other marine birds in Frederick Sound, southeast Alaska. *Canadian Field-Naturalist* 112(2): 346–347.

A total of 5920 moulting sea ducks were found at four sites characterized by shallow water foraging areas around islands and at entrances to glacial inlets.

Key Words: Surf Scoter, *Melanitta perspicillata*, White-winged Scoter, *Melanitta fusca*, Oldsquaw, *Clangula hyemalis*, Harlequin Duck, *Histrionicus histrionicus*, Alaska, moult.

Although the northeast Pacific coast is an important winter destination for sea ducks (Isleib and Kessel 1973; Campbell et al. 1990), its importance to Surf Scoters (*Melanitta perspicillata*), White-winged Scoters (*M. fusca*), Oldsquaw (*Clangula hyemalis*) and Harlequin Ducks (*Histrionicus histrionicus*) as a moulting site has largely been ignored (Isleib and Kessel 1973). Waterfowl are especially vulnerable during the moult, and it is assumed that they return to sites with low levels of disturbance by predators and abundant food supplies (Savard 1988). Information is scant on the types of locations used by moulting seaducks along the Pacific coast. Some moulting locations in British Columbia have been identified (Patch 1922; Savard 1988; Campbell et al. 1990). Isleib and Kessel (1973) referred to moulting

sea ducks using Prince William Sound but did not describe the habitats. Here, I describe four sites with large flocks of moulting sea ducks in Frederick Sound, southeast Alaska.

I circumnavigated Frederick Sound, Alaska (57°45'N, 133°35'W), by sailboat 22–28 July 1997, stopping frequently in inlets and bays. The boat was always within 5 km and often within 1 km of the shore. Side trips were frequently made by inflatable boat and kayak to search for birds. I recorded the number and location of moulting Surf Scoters, White-winged Scoters, Oldsquaw and Harlequin Ducks and noted the water depths shown on nautical charts. I counted individuals in flocks < 150 and estimated larger flocks by tallying the number of groupings of ten birds.

The fewest number of ducks among the four sites were in Pybus Bay (75 Surf Scoters and 125 White-winged Scoters), and the largest numbers were found at Holkham Bay (20 Oldsquaws, 2300 scoters and 400 Harlequin Ducks) and nearby Wood Spit (1000 scoters). Intermediate numbers were found in Thomas Bay (2000 Surf and White-winged scoters). Many of the ducks were flightless at these sites and moulted feathers were strewn on the beach at Pybus and Holkham bays. All four sites were characterized by shallow gravel beaches. Pybus Bay was a gravel shoal between two small (ca. 50 ha) islands. Sites used in Thomas Bay, Holkham Bay and Wood Spit were submerged glacial moraines at the entrance to inlets with glaciers. These sites also attracted about 2000-3000 Mew Gulls (*Larus canus*), Arctic Terns (*Sterna paradisaea*) and Marbled Murrelets (*Brachyramphus marmoratus*) and Kittlitz Murrelets (*B. brevirostris*).

Three of the four sites were at submerged moraines at the mouths of inlets. An outflow of freshwater originating from glaciers at the end of these inlets probably supply the mouths with nutrient-laden water and allow a biologically rich environment for marine invertebrates to develop. It is unknown if the sea ducks were post-breeding adults that had returned to the coast to moult their feathers, non-breeding ducks that remained on the coast through the breeding season, or a combination of both. Male scoters in eastern Canada return to winter quarters in late June following the breeding season and might join flocks of non-breeding scoters (Bédard et al. 1997; J.-P. L. Savard, personal communication).

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Observations on Quantitative Cognition in Southern Flying Squirrels, *Glaucomys volans*

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Taulman, James F. 1998. Observations on quantitative cognition in Southern Flying Squirrels, *Glaucomys volans*. Canadian Field-Naturalist 112(2): 347-349.

Maternal Southern Flying Squirrels, *Glaucomys volans*, do not appear aware of the number of nestlings in a litter. After young are relocated from one nest cavity to another, a final search of the primary nest is performed to confirm that no nestlings remain.

Key Words: Southern Flying Squirrels, *Glaucomys volans*, nestling relocation, Arkansas.

Maternal female Southern Flying Squirrels (*Glaucomys volans*) maintain auxiliary nests and move young when primary nests are disturbed or become fouled (Muul 1968; Madden 1974). Motivation in females to retrieve their young is

great, and ordinary caution may seemingly be abandoned during a search for missing offspring (Sollberger 1943; Muul 1970). Muul (1970) found that captive females would retrieve their own young, as well as those of other female squirrels and even

other rodent species. He performed two experiments in which different females moved 35 and 50 young, respectively, in continuous bouts of activity. Though Muul (1970) stated that females always "returned to the spot where the babies were presented as if searching for more," it was not clear whether the experiments noted ended with the female returning to an empty nest. If a trial nest was supplied with additional young so that the female always encountered at least two together, and she returned repeatedly to retrieve the last one, one might only assume that the retrieval motivation was strong enough to overcome any awareness of litter size. However, if the female collected all available young and returned to examine an empty nest, the implication would be that she was not aware of her litter size and simply retrieved and relocated young until a final check revealed that there were no more remaining in the original nest.

Flying squirrels are elusive nocturnal mammals, and description of female retrieval and relocation of young has not been previously described in free-ranging animals. This report presents observations on an adult female moving her three offspring from a nest box to a natural cavity after a disturbance. These observations were made in the Ouachita National Forest of west-central Arkansas (34°29'–35°05' N, 93°22'–94°30' W) during the course of a 4-year study of flying squirrel responses to a range of experimental timber harvest practices on 21 15-ha study areas (Taulman 1997).

At 1000 on 12 March 1995 (12.8 °C) I observed a free-ranging adult female Southern Flying Squirrel move three 31-day-old young (aged on this and a previous survey according to criteria of Linzey and Linzey [1979]) from a nest box located 3 m high on a mature Shortleaf Pine (*Pinus echinata*) to a natural cavity 5 m away. One young had opened its eyes; the other two had not. During routine winter nest box surveys, after removing the nest box from the tree and processing the occupants of a box containing a litter, I typically returned all squirrels to the box and hung it back on the tree in order to minimize disturbance to mothers and young. Normally, adult females did not emerge from the box after handling; about half of the time adult females appeared at the entrance to watch as we moved away. On this occasion, after processing, the female escaped while I was returning her and the young to the nest box. She immediately proceeded up the tree to the location where the box normally hung and searched for it. I placed the box back in position, returned young squirrels to the box three times after they jumped out, and then removed the ladder and moved away about 10 m.

The adult female entered the box and emerged with one young, which she carried in her mouth and manipulated with the forepaws until it was posi-

tioned beneath her chin and throat (as shown in Sollberger 1943). She then descended the trunk in a head-down orientation to within 1.5 m of the ground and jumped down, hopping along the ground to a distance of about 15 m where she disappeared near the base of a tree. Within one min another flying squirrel was observed gliding to and then climbing a mature pine 10 m from where the adult female was last seen, having apparently been ejected from its nest by the adult female. Ten min later the female came hopping back across the ground carrying the first young squirrel. After depositing it in a cavity with a 10 × 20 cm entrance at the base of a 10.8 cm dbh Sweetgum (*Liquidambar styraciflua*), 5 m away from the nest box tree, she returned to the nest box, emerging 45 s later with a second young, which she carried to the Sweetgum cavity. After 3.5 min she returned to the box and emerged with the third young after 45 s inside. Three min after depositing the last young squirrel in the natural cavity with the other two, she returned to the box. After 2 min she emerged with a small ball of cedar nesting material, jumped from the box to the ground, and reentered the natural cavity where the young had been deposited, not appearing again before observation ceased 7 min later.

In an attempt to induce additional bouts of nestling relocations, after processing the six litters discovered during the winter 1996 nest box survey I returned young squirrels to the boxes, but adult females were released separately. Females either climbed to the crown of the nest box tree or glided to nearby trees. After observation periods of 12–25 min, none of the adult females returned to the nest box nor were observed to relocate young. I assume that females later rejoined their young; no abandoned or dead young were noted in subsequent surveys. Estimated ages of the six litters varied from 11–33 days.

The extreme vulnerability of altricial flying squirrel young, particularly before eyes open (Sollberger 1943; Linzey and Linzey 1979), would seem to create an evolutionary expedient to which the female would respond by not leaving her young alone unless absolutely necessary. After relocating her young to an auxiliary nest following a disturbance at the primary nest, the motivation to remain with the young should be compelling. The fact that the female observed here returned to the nest after all young had been moved to the secondary cavity is strong indirect evidence that she was not aware of the number of young in her litter. Leaving her young unprotected to retrieve a bit of supplementary nesting material would not seem to be a strategy favored by natural selection; the wad of shredded cedar collected on the last foray to the nest box was probably taken simply because she was already there. These observations on free-ranging flying squirrels supplement the experimental results of

Muul (1970) on captives and suggest that in order to compensate for a lack of quantitative awareness the flying squirrel has evolved nestling retrieval and relocation behaviors which terminate a sequence with a final check of the empty primary nest. When no young remain the female can be certain that all have been moved.

Acknowledgments

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News and Comment

Notices

The 120th Annual Business Meeting of The Ottawa Field-Naturalists' Club

The 120th Annual Business Meeting of The Ottawa Field Naturalists' Club will be held in the auditorium of the Canadian Museum of Nature, McLeod and Metcalfe streets, Ottawa, on Tuesday 12 January 1999 at 7:30 pm (19h30h).

GARRY McNULTY
Recording Secretary

Erratum: *The Canadian Field-Naturalist* 111(4)

Page 710 in Book Review section: the correct name for the publisher of The American Museum of Natural History reviewed by Francis R. Cook is Harry N. Abrams Inc., this is a subsidiary of Times Mirror Co., 100 Fifth Avenue, New York, N.Y. 10011, USA.

Erratum: *The Canadian Field-Naturalist* 112(1)

Page 64, line 38, left column "these fluctuations" should read "low host specificity" in McAlpine, Donald F., and Michael D. B. Bert. 1998. Helminths of Bullfrogs, *Rana catesbeiana*, Green Frogs, *R. clamitans*, and Leopard Frogs, *R. pipiens*, in New Brunswick.

Sea Wind: Bulletin of Ocean Voice International

Volume 11, Number 4, 36 pages, September-December 1997, contains articles on: Survey and Review of the Philippine Marine Aquarium Fish Industry (Benjamin Vallejo, Jr.); Eco-marketing and Fair Trade for PMP Aquarium Fish Collectors (Jaime Baquero); The Nautilus is in Danger (Heike Neumeister); Alternatives to the Multilateral Agreement on Investment (MAI) (Mike Nickerson); plus the regular sections: On the Net, Sea News, and Book Nook. It concludes with the Audited Balance sheet for Ocean Voice International.

Sea Wind is available though membership in Ocean Voice International P. O. Box 37026, 3332 McCarthy Road, Ottawa, Ontario K1V 0W0, Canada; e-mail: mcall@superaje.com; World-Wide Web site: <http://www.ovi.ca>.

Froglog: Newsletter of the Declining Amphibian Populations Task Force (DAPTF)

Number 25, January 1998, contains: "Mesoamerican Decline Symposium" Erik K. Lindquist; "Amphibian Population Decline in a Honduran National Park" Larry David Wilson and James R. McCranie; "Climate Change Workshop Report" Cynthia Carey; "The Status of Amphibians in Wawushan Mountain National Forest Park" Jiang Jin-Ping and Zheng Ming-Quan; "The Status of Amphibians in Xiaman National Conservation Region" Ling Qang, Liu Shaoyin & Ran Jianhong, as well as a "Call for International Cooperation", "Froglog Shorts", and "Publications of Interest".

Number 26, April 1998, contains: "New Seed Grant Round" (one time awards of \$500 to \$2000 for support or initiation of research projects to forward DAPTF's mission); "Amphibians and trematodes" by Stan Sessions; "NIEHS Sponsors Workshop on Amphibian Deformities" by Ken Dodd; "In defense of Offham Marshes" by Trevor Beebee; "Froglog Shorts" and "Publications of Interest".

Froglog is available from Editor John W. Wilkinson, Department of Biology, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk and on the World Wide Web at the following URL: <http://acs-info.open.ac.uk/info/newsletters/FROGLOG.html>

Canadian Association of Herpetologists Bulletin

Volume 11, Number 2, fall 1997 issue contains one "Feature" — "Natural Heritage Resources of Ontario: Amphibians and Reptiles, November 1997" by Michael J. Oldham, three short "Miscellany" contributions — "The Atlas of Amphibians and Reptiles of Quebec: an Overview of the First Eight Years" by Sylvie Matte; "North American Reporting Centre for Amphibian Malformations" by Heather Gray; and "Monitoring and Management of an Unusual Population of Maritime Garter Snakes, *Thamnophis sirtalis pallidulus*, on Geroje's Island, Halifax Harbour, Nova Scotia" by Suzanne M. Barnes. There are three "Meetings" reports:

"1998 Annual Meeting of ASIH/SSAR/HL/CAH/AES" by Tana McDaniel, "Canadian Herpetologists Meet in Wolfville" by Larry Powell, "The CAH Session in Wolfville" by Brian Eaton. A section on "Publications of Interest" includes eight titles with comments by Jon Davidson and David M. Green. Two "Thesis abstracts in Canadian Herpetology" conclude the issue: "Thermoregulation in female *Phrynosoma*" M.Sc. Janice D. James, University of Calgary, and "Skeletal morphology of *Anolis garmani*" M.Sc. Mary R. Myers, University of Calgary (Supervisor for both Dr. Anthony P. Russell).

Membership in the Canadian Association of Herpetologists / Association Canadienne des Herpetologistes is \$10.00 for regular members and \$5.00 for students, payable to Dr. Patrick T. Gregory, Treasurer CAH/ACH, Department of Biology, University of Victoria, Victoria, British Columbia V8W 2Y2, Canada.

Rana-Saura: Amphibian population monitoring program; Atlas of amphibians and reptiles of Quebec

Volume 4, Number 2, December 1997, of this newsletter contains an update on the latest progress on the monitoring program which now has completed its fifth year. Included are items on changes in goals, top species for 1997, the coordinator's year end comments on road surveys and reproductive sites, urban sprawl, statistical analysis 1993-1996, a reminder of the active data bank on the distribution and frequency of malformations and diseases of amphibians by the Canadian Wildlife Service and McGill University, a list of participants for the 1997 amphibian monitoring program, and gleanings from other sources titled "I heard that" and "Surfing for herps". Finally there is a item on the 1997 contributions to The Atlas of amphibians and reptiles of Quebec.

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Global Biodiversity: Canadian Museum of Nature

Volume 7, Number 3, Winter 1997 contains features on "Turning the tide" (Amy Mathews Amos); "The paradox of parasites" (David J Marcogliese); "Assessing insect biodiversity — without wasting your time" (H. V. Danks). In addition there are 8 "Departments" sections: Portrait (marine trematode); Forum (forest biodiversity); Conference reports; Meetings; News; Cyberdiversity; Book reviews; and The Last Word (Under the Antarctic Ice — Kathleen Conlan). The issue is introduced by an "Editor's Notebook", a strong plea addressed to democratic political heads of state: "Absolutely no shortage of resources to save biodiversity!"

Volume 7, Number 4, Spring 1998, leads with an "Editor's Notebook" comparing recent environmental/economic concerns: "Ice and fire storms: The Kyoto deal". Feature articles are — "Patenting life: Progress or piracy?" by Genetic Resources International; "Using crop residues to save forests" by Al Wong, Arbokem Inc.; "Gaps in freshwater ecosystem research" Don E. McAllister, Andrew L. Hamilton, and Brian Harvey; and "Managing the Canadian forest for biodiversity" by Katja Power, Pacific Forestry Centre. Department sections are: Portrait (Bamboo); Forum (The MAI and biodiversity); Conference Report (CCIUNC); Meetings, News, Cyberdiversity, Book Reviews, Index (volume 7); and The Last Word (Towards a Natural History Museum for the 21st Century (by Joanne DiCosimo, President and CEO, Canadian Museum of Nature).

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Ontario Natural Heritage Information Centre Newsletter

Volume 4, Number 1, Winter 1997/1998 contains 16 pages and begins with a summary of the information available on the NHIC Web Page (<http://www.mnr.gov.on.ca>). This is followed by SCIENCE: 1997 Ontario Botanical Highlights; Two legumes from Manitoulin Island, New to North America; Prairie Warbler Survey in 1997; Rare Communities of Ontario: Freshwater Coastal Dunes: STEWARDSHIP: "Lands for Life" Natural Heritage Gap Analysis; Priority Sites for Conservation Action; NEWS AND NOTES: International Alvar Conservation Initiative; Great Lakes Coastal Wetlands Projects; The Nature Conservancy Eastern Heritage/Stewardship Conference; Tallgrass Prairie Recovery Plan; Queen's University Herbarium Database; Botanical Journals donated to NHC; Portions of Bill Stewart and Bill Dore Files to NHIC; NRVIS Data Loading Project; Ontario Endangered and Threatened Plant Bibliography; 1997 NHIC Information Requests; Herbarium Update; Karen Ness leaves NHIC; NCC Assists NHIC Client Services; Co-op Student Help; Publications; NHIC Information Products (listing of publications of NHIC staff since the previous lists in newsletters 2(1) and 3(1); and NHIC Staff List.

Copies can be obtained from: The Natural Heritage Information Centre, Ministry of Natural Resources, 300 Water Street, 2nd Floor, North Tower, P.O. Box 7000, Peterborough, Ontario K9J 8M5, Canada. Fax: (705) 755-2168.

Eighteen Years of CWS Publication on Acid Rain and Wildlife

Acid rain and wildlife: an annotated bibliography of Canadian Wildlife Service (Ontario Region) LRTAP Program Publications (1980-1997) by D. K. McNicol, M. L. Mallory, and J. Sechley. Technical Report Series Number 305, Ontario Region 1998, Canadian Wildlife Service, Environment Canada (92 pages).

For information on the Canadian Wildlife Service LRTAP Biomonitoring Program or to obtain copies of this publication, or any of the reports and papers listed in it, contact: Donald K. McNicol, Canadian Wildlife Service, 49 Camelot Drive, Nepean, Ontario K1A 0H3, Canada; e-mail: Don.McNicol@ec.gc.ca

Recovery: An Endangered Species Newsletter: Winter 1997

This is a 12-page publication of the Canadian Wildlife Service, Environment Canada, edited by Westhawk Associates, Ottawa, which contains: Recovery Watch — Inuit key to whale research (Keith Hay and Sue Cosens); CITES Update — Canadian Proposal Approved [a news item which includes reporting the transfer of the Wood Bison from Appendix I to Appendix II at the 10th CITES meeting of parties to the convention June 1997 in Zimbabwe to allow Canadian farmers to export farm-raised Wood Bison except to the United States which continues to ban their import]; Moving forward on protection of wild species at risk [updates pending legislation from federal, Nova Scotia, Alberta, Saskatchewan, Prince Edward Island, and Newfoundland governments]; "La Dune de Bouctouche" Endangered Piping Plover finds refuge at new Irving Eco-centre (Geraldine Arsenault) [New Brunswick]; COSEWIC Update — Preparation of plant update reports in high gear (Erich Haber); Endangered Species Recovery Fund Update — Scientists study new species [Bicknell's Thrush is one of 43 projects funded in 1997-1998]; Editorial — Getting involved with wildlife stewardship (Date Scobie); Essay —

Endangered wildlife a priority for all (David Wylynko); Renew update — Warbler nest box program a success (Jon McCracken) [Prothonotary Warbler, Ontario]; Profile — Endangered snake finds a home: Feltz family farm a refuge for the Blue Racer [Peelee Island, Ontario] (Ben Porchuk); Nova Scotia's natural treasures — Recovery plan underway for coastal plain plants (Alex Wilson); Seeing Wildlife through the forest [*Loggers for Wildlife* educational program of the Canadian Forestry Association] (David Wylynko); Biologists marvel at peregrine's migration [from nesting area in Wood Buffalo Park 20 August 1997 in northern Alberta to wintering area 80 km south of Veracruz, Mexico, 11 September] (Geoff Holroyd); and Featured Species: The return of a "keystone predator" [Sea Otter successfully reintroduced at a remote portion of coast of Vancouver Island, as well as Washington State and southeast Alaska] (Jane Watson).

The newsletter *Recovery* is ISSN: 0847-0294, and available free from Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada. It is also accessible at:

<http://www.ec.gc.ca/cws-scf/es/recovery/eng/index.html>

CITES Control List Number 12

Environment Canada has produced the twelfth version of the list of all animal and plant species (including their parts and derivatives) controlled under Appendices I, II, and III, of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). This version is dated 18 September 1997 and includes the amendments of the Tenth Meeting of the conference of Parties to CITES held in Zimbabwe in June 1997. Also part of the text

is an interpretation of the Appendices, an addendum listing genera included in higher taxa, and an index.

Copies of this 59-page booklet, the Act itself and its Regulations may be obtained from: Administer, Convention on International Trade in Endangered Species, Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3; Telephone (819) 997-1840; Telefax (819) 953-6283; internet: <http://www.ec.gc.ca/cws-scf>

Wildlife as Indicators of Forest Sustainability

The Wildlife Section, Fish and Wildlife Branch, Ministry of Natural Resources has published a 42-page analysis: *Selection of Wildlife species as indicators of forest sustainability in Ontario* Edited by Margaret A. McLaren. 1998. SCSS Technical Report number 100, Queen's Printer, Ontario (Ministry of Natural Resources 50979: ISSN 1206-

0607). This is a summary of a workshop held at Peterborough, Ontario, on 18-19 March 1997, and subsequent recommendations. The bulk of the publication is 8 Tables (covering criteria for selection of species: habitat types; Great Lakes — St. Lawrence and Boreal candidate amphibians, reptiles, mammals, and birds; final candidate species) and 3

Appendices (workshop organizers and invitees; Great Lakes and Boreal final indicators; scientific names of species in tables).

Copies can be obtained from Ontario Ministry of Natural Resources, Southcentral Science Section, 3301 Trout Lake Road, North Bay, Ontario P1A 4L7.

Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade ACT: 1996 Report

This 21-page English and 24-page French publication of the Canadian Wildlife Service, Environment Canada, is the first annual report of the implementation of the *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act* (WAPPRIITA). It is Public Works and Government Services Canada, 1998. Catalogue number CW70-5/1996: ISBN 0-662-63443-8. As outlined in the introductory message from the honourable Christine S. Stewart, Minister, WAPPRIITA and the Wild Animal and Plant Regulations became law in Canada May 1996. WAPPRIITA makes it an offense to import wildlife products that have been illegally obtained or illegally exported from other countries and becomes the means for Canada to honour its obligations under the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES). Within Canada, WAPPRIITA gives national support to provincial and territorial legislation, making it an offense to be in possession of animals or plants, if

obtained illegally in one area, anywhere in Canada. The publication is in sections: Introduction; Regulation, Compliance, and Enforcement; International Cooperation; and Sources of Further Information. The latter lists Administration addresses for both Environment Canada and Fisheries and Oceans, and Enforcement offices both National and Regional, as well as wildlife/fish/resources departmental addresses for each province and territory from which to obtain more information for both CITES export permits and provincial and territorial requirements with regard to wild animals and plants regulated by provincial and territorial governments. Directions are also given to "Environment Canada's Green Lane" on the internet at <<http://www.ec.gc.ca/envhom.htm>> which will provide up-to-date information on Environment Canada's activities and, in particular, to its WAPPRIITA-related activities, including specific permit and other requirements for CITES-listed species as well as publications lists and ordering information.

the Ontario chorus

Volume 1, Number 4, January 1998, of this newsletter for volunteer amphibian monitoring programs highlighting programs and focuses on issues of concern to Ontario herpetologists, environmentalists and program volunteers. Items included are: How good are call count surveys for monitoring changes in population size?: FX-files, deformed frogs and pollywogs; Canadian Amphibian and Reptile

Conservation Network: Changes for 1998; Quiz: You thought you had it bad, And don't forget the marshes!; Celebrate Wildlife Week April 5-11, 1998.

For copies and more information on Ontario amphibian monitoring contact: Canadian Wildlife Service, Environment Canada, Canada Centre for Inland Waters, 867 Lakeshore Road, Burlington, Ontario L7R 4A6.

The Boreal Dipnet: Newsletter of the Canadian Amphibian and Reptile Conservation Network

Volume 2, Number 2, Spring-Fall 1997 issue of this publication of the Canadian Amphibian Conservation Network includes the Task Force on Declining Amphibian Populations in Canada (DAPCAN). Featured are: CARCN is finally charitable: We are now on the web: The Wolfville Conference: Field trip to Kejimikujik: Happenings in western Canada: A tribute to David Green: Two new lizard species [created by the split of the former *Phrynosoma douglassii* into *P. douglasi* and *P. hernandezii*]; EMAN monitoring workshop: Deformed frogs and pollywogs; NASA and the Changing Climate; World Congress of Herpetology; New

herp education group; DAPTF General Meeting results; Declining Amphibian Symposium; Australian hold frog forum; What's the buzz? ["The problems with lists"]; Update from Alberta; Please help the CARCN/ RCCAR: 1st invitation to Saskatoon Meeting: Books, stickers & T-shirts.

For additional information contact the Stan Orchard, Editor, the Boreal Dipnet, Canadian Amphibian and Reptile Conservation Network/Reseau Canadien de Conservation des Amphibiens et des Reptiles, 1745 Bank Street, Victoria, British Columbia or visit their web site at <http://cciw.ca/eman-temp/ecowatch/depcan>.

Editor's Report for *The Canadian Field-Naturalist* Volume 111 (1997)

Research, observation, synthesis, or tribute manuscripts submitted to *The Canadian Field-Naturalist* totalled 119 in 1997, a decrease of 6 from 1996, but 14 more than 1995, and 32 more than in either 1993 and 1994. Of the new submissions in 1997, 23 were still with reviewers at the end of the year; 38 sent back for revision or rejected had not been returned; and 58 had been accepted as of 31 December. The time from receipt to acceptance for the accepted manuscripts in 1997 varied from 14 to 310 days (mean 121.9 days), with the time between receipt and return taking up to 198 days of this, with a mean of 84.8 days. Also accepted this year were 39 revisions of papers first submitted in 1984(1), 1994(1), 1995(3), and 1996(34). Only seven papers submitted in 1997 appeared in this year, all in 111(4). The majority will appear in 1998: 112(1) and 112(2) are filled, and seven are accepted for 112(3). A special issue on the history of the Canadian Wildlife Service 1947-1997 by Alexander Burnett commissioned by the CWS has been delayed and likely will not appear until 113(1) in 1999.

Acceptance for manuscripts has been 85%, 88%, and 85% for 1994, 1995, and 1996; this includes many requiring extensive author rewriting and revision but still not counted as new when re-submitted, even after considerable delay. Reviewing and revision is incomplete for 1997 and was 47% at the end of the year. Acceptance rates have climbed markedly since the 1970s (see Cook 1981 *The Canadian Field-Naturalist* 96(2): 220-223) when they had dipped to 62-65% between 1976 and 1980, but some of this apparent difference may be due to different accounting procedures, fewer unsuitable papers being submitted, and the number of solicited papers being included in recent totals.

Totals for circulation to members of the Ottawa Field-Naturalists' Club and individual and institutional subscribers to *The Canadian Field-Naturalist* in 1997 together with those of 1996 are given in Table 1. Total copies distributed were down slightly compared to the previous year.

Issue mailing dates for volume 111 were: (1) 2 May 1997, (2) 16 June 1997, (3) 1 August 1997, and (4) 12 November 1997 (though the postal strike 19 November lasting til 9 December delayed delivery of all but some Ottawa copies). This is the first time an final issue for a year was mailed as early as November since 1979, when 93(4) was mailed 13 November 1997. The volume totalled 750 pages; the largest single issue (4) was 208 pages. The initial issue, 111(1), "The Orchids of the Ottawa District" by Joyce and Allan Reddoch was the third special issue produced in the last three years, and special thanks are due to authors for their detailed shepherding of this at every stage through to publication; far, far beyond that normally given by authors.

The number of articles and notes in volume 110 is summarized in Table 2 by topic. The totals for Book Reviews and New Titles are given in Table 3, and the distribution of published pages among issues in Table 4.

M.O.M. Printers, 300 Parkdale Avenue, Ottawa, set and printed the journal and special thanks are due Emile Holst, to Eddie Finnigan (who retired early in the year), and to Yoland, Cecilia, and Bruce. Wanda J. Cook proof-read the galleys for the volume. Bill Cody continued as Business Manager and also oversaw the compilation, and proof-read and edited, the Index for volume 111 which was diligently prepared by Leslie Durocher. Wilson Eedy continued as Book-Review Editor, including compilation of New

TABLE 1. The 1997 circulation of *The Canadian Field-Naturalist* (1996 in parenthesis). Membership totals from Annual Report of The Ottawa Field-Naturalists' Club (*in press*), subscription totals compiled by W. J. Cody. Forty percent of membership dues and 100% of subscriptions go to production of *The Canadian Field-Naturalist*. Members vote on Club affairs, subscribers and institutions do not.

	Canada	USA	Other	Totals
Memberships				
Family & Individual	939 (987)	32 (32)	5 (5)	976 (1024)
Subscriptions				
Individuals	173 (186)	55 (62)	5 (6)	233 (254)
Institutions	186 (198)	257 (267)	43 (46)	486 (511)
Totals	359 (384)	312 (329)	48 (52)	719 (765)
TOTALS	1298 (1371)	344 (361)	53 (57)	1695 (1789)

Note: 20 countries are included under "Other" (outside Canada and United States): Institutions: Australia 2, Austria 1, Belgium 1, Brazil 1, Denmark 1, England 8 (including Northern Ireland 1), Finland 5, France 2, Germany 3, Japan 2, Netherlands 2, New Zealand 1, Norway 4, Poland 1, Russia 1, South Africa 1, Spain 2, Sweden 2, Switzerland 3; Subscribers: England 1, Finland 1, Netherlands 1, Norway 1; Members: England 2; Finland 1; France (St. Pierre & Miquelan Islands) 1, Iceland 1.

Titles, despite his continuing world travel on other duties (his detailed annual report will appear separately). George La Roi continued to serve as Coordinator of the Biological Flora of Canada (a summary of this series is still pending).

All article and note manuscripts submitted to *The Canadian Field-Naturalist* are normally reviewed by at least one associate editor and usually by one or more additional reviewers as well. This combines the opinions of associate editors who review the majority of manuscripts submitted in a field through the year with those of outside specialists (chosen by the editor or an associate editor, or selected from alternates suggested by authors) who may see only one (but sometimes more) CFN manuscript(s) a year. This produces a balance by providing both consistency of opinion on one hand and freshness on the other. The editor makes the final decisions on manuscripts and corresponds with the authors, largely based on the advice of all reviewers. I am indebted to all who returned reviews in 1997 (with number, if more than one, in parenthesis):

Associate Editors -- Mammalogy: William O. Pruitt, Jr., University of Manitoba, Winnipeg (25); Warren B. Ballard, Arizona Game and Fish Department, Phoenix (21); Ornithology: Anthony J. Erskine, Sackville, New Brunswick (30); W. Earl Godfrey, Canadian Museum of Nature, Ottawa, Ontario (3); Fish and Marine Mammals: Robert R. Campbell, Woodlawn, Ontario (2; plus 8 COSEWIC status reports); Ichthyology: Brian W. Coad, Canadian Museum of Nature (9); Entomology: R. Anderson, Canadian Museum of Nature (5); Botany: Charles D. Bird, Erskine, Alberta (27), and Paul M. Catling, Agriculture Canada, Ottawa (13).

Additional reviewers -- David Anderson, University of Minnesota; B. Theresa Aniskowicz, Canadian Wildlife Service, Hull, Quebec; Ray

Alisaushas, Canadian Wildlife Service, Saskatoon, Saskatchewan; C. Davison Ankney, University of Western Ontario, London, Ontario (3); George Argus, Canadian Museum of Nature, Ottawa; Jack F. Barr, Guelph, Ontario (2); Valerie Behan-Pelletier, Agriculture and Agri-food Canada, Ottawa; Rene J. Belland, University of Alberta, Edmonton; Keith Bildstein, Hawk Mountain Sanctuary, Pennsylvania; David M. Bird, McGill University, Ste. Anne de Bellevue, Quebec; Lawrence Blus, National Biological Service, Corvallis, Oregon; Jeff Bowman, University of New Brunswick, Fredericton (2); Bridgit Braune, Canadian Wildlife Service, Ottawa; Ralph Brinkhurst, Aquatic Resources Centre, Franklin, Tennessee; Daniel F. Brunton, Ottawa, Ontario; Ludwig Carbyn, Canadian Wildlife Service, Edmonton, Alberta (5); R. Wayne Campbell, British Columbia Ministry of Environment, Victoria; Francois Chapleau, University of Ottawa; Kimberly M. Cheng, University of British Columbia, Vancouver (2); William J. Cody, Agriculture and Agri-food Canada, Ottawa (5); Joseph A. Cook, University of Alaska Museum, Fairbanks; Vince Crichton, Manitoba Natural Resources, Winnipeg; E. J. Crossman, Royal Ontario Museum, Toronto (2); Ken De Smet, Manitoba Natural Resources, Winnipeg; Andrew Didiuk, Canadian Wildlife Service, Saskatoon, Saskatchewan; George W. Douglas, British Columbia Ministry of Environment, Victoria; Judy Enck, Cornell University, Ithaca, New York; Jim Fargo, Alaska Department of Fish and Game, Silka; Graham Forbes, University of New Brunswick, Fredericton; Lisa M. Fox, Yukon-Chanley Rivers National Preserve, Eagle, Alaska; T. D. Galloway, University of Manitoba, Winnipeg; Anthony J. Gaston, Canadian Wildlife Service, Hull, Quebec (2); Patrick T. Gregory, University of Victoria, British Columbia; Erich Haber, National Botanical Services, Ottawa (7); Brenda Hahn, University of Manitoba, Winnipeg; Fred Harrington, Mount St. Vincent University, Halifax, Nova Scotia; Erling Holm, Royal Ontario Museum, Toronto (2); Robert Ireland, Nepean, Ontario; Pat Kehoe, University of New Brunswick, Fredericton; Anthony Keith, Canadian Wildlife Service, Hull, Quebec (2);

TABLE 2. Number of articles and notes published in *The Canadian Field-Naturalist* Volume 111 (1997) by major field of study.

Subject	Articles	Notes	Total
Mammals	22	16	38
Birds	8	10	18
Amphibians and reptiles	1	1	2
Fish	2	2	4
Invertebrates	2	2	4
Plants	13	7	20
Other	3*	0	3*
Totals	51	38	89

*COSEWIC Fish and Marine Mammal Subcommittee report 111(2). In addition, there was a paper on both plant and animal diversity in 111(3), and one tribute article (Harold Senn) in News and Comment section 111(4).

TABLE 3. Number of reviews and new titles published in Book Review section of *The Canadian Field-Naturalist* Volume 111, by topic.

	Reviews	New Titles
Zoology	49	69
Botany	10	33
Environment	33	60
Miscellaneous	7	11
Young Naturalists	0	54
Totals	99	227

TABLE 4. Number of pages published in *The Canadian Field-Naturalist* Volume 111 (1997) by section (number of manuscripts in parenthesis).

Issue number:	- 1 -		- 2 -		- 3 -		- 4 -		Total
Reports: Research/Observations									
Articles	185	(1)	121	(18)	95	(15)	85	(13)	486 (47)
Notes	—	—	15	(7)	29	(13)	38	(18)	82 (38)
News and Comment									
Notices	1	(1)	8	(9)	4	(6)	5	(13)	18 (29)
Annual Meeting	—	—	7	(1)	—	—	—	—	7 (1)
Comment Articles	—	—	5	(1)	33	(2)	5	(1)	43 (4)
Book Reviews*	—	—	16	(21)	23	(29)	40	(49)	79 (99)
Index	—	—	—	—	—	—	33	(1)	33 (1)
Advice to Contributors	1	(1)	—	—	—	—	1	(1)	2 (2)
Total pages:	186		172		184		208		750

*Total pages for book review section include both reviews and new titles listings but parenthesis figures include only the number of reviews.

Murray J. Kennedy, Alberta Department of Agriculture, Edmonton; Matthew D. Kirchhoff, Alaska Department of Fish and Game, Douglas; Donald LaFontaine, Department of Agriculture and Agri-food, Ottawa; Bernard Landry, Aylmer, Quebec; Ted Leighton, University of Saskatchewan, Saskatoon; Ross D. MacCulloch, Royal Ontario Museum, Toronto; Andre Martel, Canadian Museum of Nature, Ottawa; Carl D. Marti, Weber State College, Ogden, Utah; W. Brian McKillop, Manitoba Museum, Winnipeg; Ian McLaren, Dalhousie University, Halifax, Nova Scotia; L. David Mech, U. S. Fish & Wildlife Service, St. Paul, Minnesota; W. Bruce McGillivray, Provincial Museum of Alberta, Edmonton; Sterling Miller, Alaska Department of Fish and Game, Anchorage; Gerald A. Mulligan, Canada Agriculture and Agri-food, Ottawa; David Nagorsen, Royal British Columbia Museum, Victoria (2); Thomas D. Nudds, University of Guelph, Ontario; Michael J. Oldham, Ontario Ministry of Natural Resources, Peterborough (2); Henri Ouellet, Hull, Quebec; Gerry Parker, Canadian Wildlife Service, Sackville, New Brunswick; Pamela J. Pietz, Northern Prairie Science Center, Jamestown, North Dakota; Lawrence Powell, University of Calgary, Alberta; William B. Preston, Manitoba Museum, Winnipeg; Michael Raine, Golder Associates Limited, Calgary, Alberta; Randall Reeves, Okapi Wildlife Associates, Hudson, Quebec; T. B. Reynolds, Canada Centre for Inland Waters, Burlington, Ontario; Raleigh J. Robertson, Queens University, Kingston, Ontario; Reed C. Rollins, Harvard University, Cambridge,

Massachusetts; Anthony P. Russell, University of Calgary, Alberta; Dwayne Sabine, University of New Brunswick, Fredericton; Dianne Secoy, University of Regina, Saskatchewan (2); Tony Scheuhammer, Canadian Wildlife Service, Hull, Quebec; Spencer G. Sealy, University of Manitoba, Winnipeg (2); K. W. Stewart, University of Manitoba, Winnipeg (6); Edmund S. Telfer, Canadian Wildlife Service, Edmonton, Alberta; Ian D. Thompson, Forestry Canada, Saulte Ste-Marie, Ontario; Jim Troubridge, Langley, British Columbia; C. G. Van Zyll de Jong, North Augusta, Ontario; Dale Vitt, University of Alberta, Edmonton; Dennis Voigt, Ontario Ministry of Natural Resources, Maple; Michelle Wheatley, Sahtu Renewable Resources Board, Norman Wells, Northwest Territories (2); Heather Whitlaw, Phoenix, Arizona; Keith Winterhalder, Laurentian University, Sudbury, Ontario; Daniel E. Wujek, Central Michigan University, Mount Pleasant.

I am also indebted to David Moore, President of The Ottawa Field-Naturalists' Club, the Club Council, to Chairman Ron Bedford and the Publications Committee of the OFNC for their support, to the administration and staff of The Canadian Museum of Nature for allowing me continued use of the library and the facilities at the new National Heritage Building, 1740 Pink Road, Aylmer, Quebec, and to Joyce for continuing encouragement at home throughout another year.

FRANCIS R. COOK
Editor

A Tribute to William George Dore, 1912–1996

STEPHEN J. DARBYSHIRE

Eastern Cereal and Oilseed Research Centre, Wm Saunders Building #49, Central Experimental Farm, Agriculture and Agri-Food, Canada (Ottawa, Ontario K1A 0C6, Canada)

Darbyshire, Stephen J. 1998. A tribute to William George Dore, 1912–1996. *Canadian Field-Naturalist* 112(2): 357–365.

William George Dore was born in Ottawa, 17 April 1912, to Charles Francis Dore and Evelyn Beeman Storr. His siblings included Jackson Ira Dore, Richard Francis Dore and Beatrice Maud Moore. In 1942 he married Doris Annabella Robbie of Aberdeen, Scotland. Bill Dore died on his 84th birthday, 17 April 1996, a few kilometres from where he was born.

An interest in science came at an early age and Bill excelled in the subject at high school. No doubt encouragement and stimulation came from his two brothers who had similar interests; Jackson became a chemist for the National Research Council and Richard a consulting engineer. His mother was fascinated by photography and took many photographs of Ottawa in the early decades of the century. Early childhood summers were spent at the cottage built by his father at Danford Lake, Quebec, which was called The O-Kum-Inn. Long days of boyhood rambling brought Bill an intimate knowledge of the natural history of this area. He continued visiting the cottage until the 1980s when it became physically difficult to do so. Until the cottage was finally sold by the Dore family in the 1980s, it remained one of the last dwellings on Danford Lake without electricity or plumbing.

In September 1930 Bill enrolled in the biology department at Queen's University in Kingston. A few months later, in February of 1931, he bought a copy of *Gray's New Manual of Botany* (7th edition, by B. L. Robinson and M. L. Fernald) and began his study of the Canadian flora in earnest. In 1933 he received his BA (Honours) from Queen's University with the Gowan Foundation Award in Botany. In 1934 Bill began a post-graduate degree in bacteriology at Queen's University but this was not completed. In his early under-graduate days Bill worked as a leader at the Y.M.C.A. boys' camp at Shirley's Bay (west of Ottawa). This brought him into close contact with another active participant of the camp, Herb Groh (1883–1971). Mr. Groh was a weed biologist at the Division of Botany of the Dominion Experimental Farm in Ottawa (now Central Experimental Farm, Agriculture and Agri-Food Canada) and no doubt assisted in getting Bill a summer job there in 1932. From 1933 to 1937 he was employed by both MacDonald College and the Dominion Experimental

Farm on pasture studies. In 1935 he received a M.Sc. degree in Agronomy and Botany from McGill University (MacDonald College). Another formative event of this year was a lecture given at MacDonald College by Marie-Victorin (1885–1944). At the end of the lecture Bill managed to acquire one of the first available copies of *Flore Laurentienne*, which Marie-Victorin kindly inscribed. Subsequently Bill rapidly filled the large margins of the first edition with critical comments and notes. From 1937 to 1946 he was Lecturer, and later Assistant Professor, in Botany at Dalhousie University, Halifax, Nova Scotia. At Dalhousie Bill taught courses in botany, bacteriology, ecology, physiology, and the flora of Nova Scotia. In 1946 he moved to the University of Guelph as assistant, and later associate, lecturer in botany for two years. In 1947, he returned to the Dominion Experimental Farm in Ottawa where he worked until his retirement in 1976. He had began his Ph.D. studies at Ohio State University in 1938 under the famous grassland ecologist Edgar N. Transeau (1875–1960). The war and the domestic demands of a young family interrupted his studies, but in 1948 he completed his thesis, *Pasture Associations of Eastern Canada*, and was awarded a Ph.D. in Ecology.

During his career Bill pursued many aspects of botany. He was interested in anatomy, physiology, phytogeography, ethnobotany and ecology, but all these aspects of botany and their ramifications lead him back to systematics and identification. His interest in pasture studies and the difficulties in field identification of plants grazed by cows, lead to his participation in the production of one of the first publications specifically on the identification of grasses by vegetative characteristics (Nowosad, Newton Swales, and Dore 1936). The preface to the second edition (1938) begins with "The fact that the first edition of this modest bulletin, designed only to meet a local need, met with a profuse and world wide demand, is evidence of the rising interest in grassland research. Combined, however, with a steady stream of letters of appreciation from pasture workers everywhere and even from leading taxonomists, this unexpected response has led the authors and sponsors of the bulletin to believe that a new revised edition may prove useful." This was characteristic of many of the publications of Bill Dore. In



William (Bill) G. Dore. Ottawa, January 1949.

Dore. In his writing he was attentive not only to a specialized scientific audience, but also to a wider, less technical readership. Other landmark publications written in this vein which have enjoyed great popularity include *Wild-rice* (Dore 1969) and *Grasses of Ontario* (Dore and McNeill 1980). These important references are not just compilations of the work of others, but full of unique observations made over many years of careful field observation and backed up by laboratory and cultivation studies.

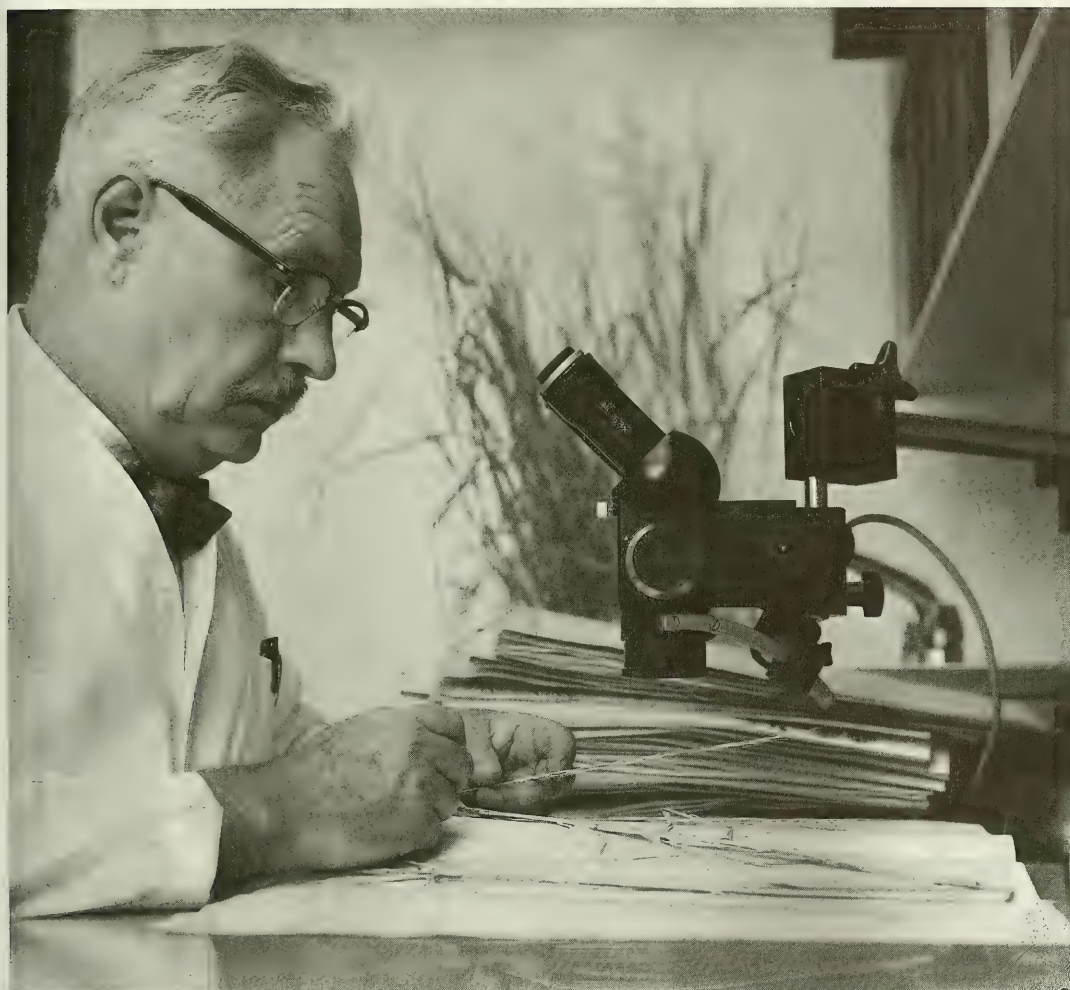
From his earliest collections Bill showed a strong preference for grasses and grass-like plants. No notebooks documenting his plant collections were made prior to 1945, although he collected widely in southern Ontario, Quebec and especially Nova Scotia. In 1945 he travelled widely in the Maritime provinces with ecologist Evile Gorham (1925-) collecting a broad range of plants, including lichens and mosses. Part of this work resulted in a paper by Gorham on the occurrence of mosses and lichens in pastures (*Proceedings of the Nova Scotian Institute of Science* 22: 1-10, 1947). Mosses were a secret love of Bill, which unfortunately, he was unable to pursue with much vigour. In addition to collecting widely in the Maritime provinces, southern Quebec and southern Ontario, other collecting areas included southern Manitoba and western Ontario (1948), Churchill,

Manitoba (1949), the southern Prairie Provinces (1950), New York and Wisconsin (1953), Vermont (1961), Manitoba (1961), Alberta (1963), southern Saskatchewan (1974) and British Columbia (1974). After retiring Bill continued to collect valuable specimens, making trips to southern Alberta, southern Manitoba, Nova Scotia, and western Newfoundland, as well as to old stomping grounds in eastern Ontario and western Quebec.

Bill's collections of plant specimens, which populate most herbaria in Canada and many herbaria around the world, form a lasting contribution to Canadian botany. The significance of these collections is difficult to fully evaluate. An idea of their value can be seen by the many citations of his collections in the botanical systematic literature and by the inclusion of his collections among the type material for at least 25 names of Canadian plants. With collections numbering in the tens of thousands, most of



Bill Dore examining giant wildrye (*Leymus cinereus* (Scribn. & Merr.) Å. Löve) in his experimental nursery at Ottawa. Growing plants in the nursery was a critical part of Bill's research. This allowed observations on phenology and growth characteristics not easily seen in the field and an assessment of the environmental influence on genetic expression. Ottawa, July 1963.



A formal portrait of Bill Dore working on wild-rice (*Zizania palustris* L.) at the William Saunders Building, Central Experimental Farm. Wild-rice was one of Bill's major interests and through his work we have gained a much greater understanding of the taxonomy and biology of Canada's only native cereal. Ottawa, August 1969.

which included duplicates, there are few Canadian botanists who have collected the Canadian flora as broadly, either taxonomically or geographically. There are few vascular plant species known for Canada for which there is not at least one Bill Dore specimen in the collection at the Agriculture and Agri-Food Canada (Canadian Department of Agriculture) herbarium in Ottawa (DAO). These specimens are of excellent quality and frequently document unusual distributions or poorly known life history traits. As the years of collecting went by, Bill's labels tended to get longer and longer. His specimen label data are often supplemented with ecological observations, photographs, letters, drawings, historical notes, humorous anecdotes, or other "value-added" notations.

As a phytogeographer Bill was acutely interested in documenting the absence of plant species as well as their presence. The imprecision of documenting absences was a problem to which he gave much attention. Possibly as a result of his training with Transeau, Bill was never satisfied with establishing a pattern of occurrence and absence. Present distribution patterns have causal events and circumstances which he continually sought to uncover. As he maintained, Canada is probably the most interesting and fruitful area for the research of plant distribution and migration because of the "clean slate" produced by the Wisconsin glaciation less than 10 000 years ago.

Combining his interests in phytogeography, history with ethnobotany, Bill is well known for his hypotheses of aboriginal and early European influ-

ence on the distribution of plants in Canada. Explanations of unusual distributions of plants were postulated based on the deliberate utilitarian use and accidental transport. Each case was linked to the biology, dispersal properties and potential usefulness of the plant species involved. Although many people have been quick to reject these explanations of present day plant distribution, few have offered contesting hypotheses to explain "how" and "why".

Bill's interests in phytogeography and plant migration lead to a number of interesting studies. A war-time need for milkweed fluff as a substitute for kapok lead to his development of a rapid survey technique of populations in southern Ontario and southwestern Quebec. Many miles of driving roads and rapidly estimating densities resulted in a landmark publication with Herb Groh on milkweed distribution. The introduction of new weeds to Canada suggested unique opportunities to Bill for the study of plant migration. The work on Persian Darnel (*Lolium persicum* Boiss. & Hohen. ex Boiss.) in the prairies and Frogbit (*Hydrocharis morsus-ranae* L.) in Ontario and Quebec provided unique baseline information on these specific weed problems as well as the more general phytogeography aspects of establishment and spread into new areas. Interests in relating plant distribution to past events stimulated Bill to initiate several far-sited floristic studies. Most important among these were the inventories of the flora of Mont Ste.-Marie (Quebec) prior to development of the area and a study (with J. M. Gillett) of the plants of the St. Lawrence River Seaway area prior to the major flooding of the area in the 1960s.

The Ottawa Field Naturalists' Club records state that Bill joined in 1944, remaining an active member for the next 52 years. Other sources of information, however, indicate that he was attending club activities as early as 1930. From 1948 to 1958 he served the club as a member of council and from 1950 to 1966 he acted as associate editor (for botany) for *The Canadian Field-Naturalist*. His many contributions to both *The Canadian Field-Naturalist* and *Trail & Landscape* are given in the list of his publications in Appendix 2. In 1972, Bill was awarded a honorary membership in The Ottawa Field Naturalists' Club in recognition of his outstanding contributions to the knowledge of Canadian botany, his service to the club, as well as the many extremely popular field trips which he lead.

Bill Dore will be known to most members of the Canadian Botanical Association (CBA) as one of the founding members and as an enthusiastic participant in the association, attending all the annual meetings until the Victoria meeting in 1988. After 1988, Bill's health was not stable enough for extended travel. He had a major role in helping to develop the CBA logo where he took great pains to insure botanical accuracy of the sugar maple design. As the most eminent

authority of Canadian botanical history it was Bill who suggested that the CBA's most prestigious honour be named for George Lawson (1827–1895), a formative figure in Canadian botanical science (Rousseau and Dore 1966).

The love that Bill had for history and his native town can be seen in his poem *Bytown Chantey*. This poem, or chantey, was submitted for the "Heritage Competition" on the event of the 150th anniversary of the City of Ottawa in 1976. Although it was Bill's first attempt at this sort of writing, he won first prize.

Bytown Chantey (In droll monologue with appropriate Irish, Scottish and French accents; Chorus to fiddle and handclap).

Champlain, he liked le rideau,
Brebeuf bore Croix for all,
Sarg French did make the survey -

But, John By did it all!
But John By did it all, my Boys,
And John By did it all.
It cost The Crown a pritty poun(d) —
But, John By did it all!

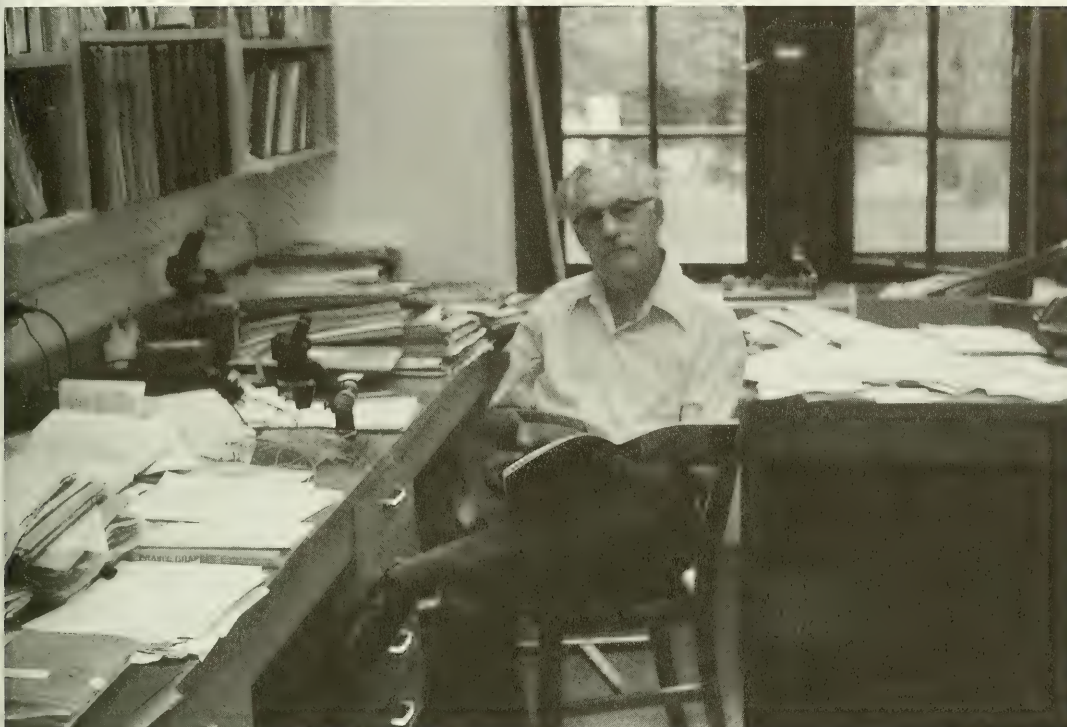
Wright rigged up his sawmill,
Brad Billings helped him saw,
Nick Sparks tracked off his cowpath lot —

But, John By did it a' !
But John By did it a', my Boys,
And John By did it a'.
It cost The Crown a pritty poun(d) —
But, John By did it a' !

MacKay sat Christmas in The Swamp,
LeBreton raged in awe,
The Queen, she smiled on Shantytown —

For, John By did it a' !
But John By did it all, my Boys,
And John By did it all.
It cost The Crown a pritty poun(d) —
But, John By did it all!

Like his greatly respected and long-time colleague at the federal department of agriculture, Bernard Boivin (1916–1985), Bill was an independent thinker. His work always showed great originality even when his unique style and approach was tempered by reviewers and editors. As a keen observer, Bill sought patterns in a context of space and time. Observations of patterns were always followed by the question "Why?" The next step was to develop hypotheses for which he frequently devised his own tools to test. Although he had great respect for colleagues, he was properly sceptical, challenging and always seeking empirical evidence to support or refute conclusions of others. This critical nature and desire for completeness was a great strength, but sometimes a hinderance throughout his career. As the world renowned grassland ecologist R. T.



Bill Dore as he was to be found in his office at the William Saunders Building, Central Experimental Farm. His wealth of botanical and historical knowledge, as well as the usual enthusiastic reception, brought many colleagues and students to the spot where this photograph was taken. Ottawa, August 1971.

Coupland (1920-) has said of Bill, "That man thinks deep."

Canadian botanists will remember Bill as a warm and delightful individual with a unique sense of humour. The work of most contemporaries pursuing phytogeography, floristics, horticulture, botanical systematics, history or ecology in Canada will have benefited at one time or another from his vast knowledge and kind generosity. Colleagues and friends will miss his enthusiasm, persistence, unique powers of observation, penetrating insight and keen wit.

Many of Bill's working notebooks and field notebooks remain at the herbarium of Agriculture and Agri-Food Canada in Ottawa. A large volume of his letters, papers, notes, un-published manuscripts and various reliquae will be deposited at the archives of Dalhousie University, including his extensive files on George Lawson.

Bill is survived by his three children: Kathleen Mary Layton (Winnipeg), David George Dore (Ottawa) and Evelyn B. Dore (Carp, Ontario).

Other obituaries:

Ceska, A. 1996. Bill Dore. Botanical Electronic Newsletter 135.

Darbyshire, S. J., and J. Gillett. 1996. Bill Dore. Trail & Landscape 30: 92-93.

Darbyshire, S. J. 1996. W. G. (Bill) Dore — 1912-1996. Canadian Botanical Association Bulletin 29: 51-52.

Acknowledgments

I thank J. Cayouette, W. J. Cody, and J. M. Gillett for making comments on the manuscript. The assistance of Bill Dore's surviving children is greatly appreciated. Because of their concern, most of his papers and letters have been preserved and will be available to researchers in the future.

Appendix 1

The employment history of Bill Dore during the early years of his career has been hard to determine with certainty. After graduating from McGill University in 1935 until 1947, when he joined the Canadian Department of Agriculture on a permanent basis, he was involved with many projects. Primarily he was a lecturer in botany at Dalhousie University, taking summer employment with the Canadian Department of Agriculture and the Nova Scotia Department of Agriculture to work on various research projects.

Glebe Collegiate Institute (High School), Ottawa:
Junior Matriculation 1928

- Honour Matriculation 1929 with graduation award of "First in Science"
- 1929 and 1930, summers: instructor in Nature Study, Y.M.C.A. Boys' Camp, Ottawa.
- 1931, May-October: Canadian Department of Agriculture — student assistant in botany (weed eradication and pasture surveys).
- 1932, May-October: Canadian Department of Agriculture — student assistant in botany (weed eradication and pasture surveys).
- 1933, April-May: Canadian Department of Agriculture — student assistant in botany.
- 1933, Queen's University: B.A. (Honours) in botany and chemistry; Gowan Foundation Award in Botany.
- 1933-1935: Graduate Assistant, Macdonald College Pasture Project (southern Quebec).
- 1935, McGill University: M.Sc. in agronomy and botany (*cum laude*).
- 1935, September-1936, September: Canadian Department of Agriculture — graduate labourer (pasture Surveys at experimental farms in southern Quebec; identification of grasses).
- 1937, July-August: Queen's University, Instructor in Plant Taxonomy, Summer School 1937.
- 1937-1946: Lecturer (1937-1943), and later Assistant Professor (1943-1945), in botany Dalhousie University
- 1938, May-July: visiting worker, Welsh Plant Breeding Station, Aberystwyth, Wales, with Professor R. G. Stapledon.
- 1940, summer: Botanical survey of pastures in Nova Scotia.
- 1941, summer: Grassland Ecologist, Quebec Department of Agriculture.
- 1942, summer: Vegetation survey of King's County, Nova Scotia (under the direction of the Provincial Botanist).
- 1943, June-September: Canadian Department of Agriculture-Agricultural Assistant Grade 11, Native Rubber Plants Investigation-Milkweed survey of eastern Ontario.
- 1944, May-September: Canadian Department of Agriculture-Agricultural Assistant Grade 11, Native Rubber Plants Investigation-Milkweed survey of Ontario and Quebec.
- 1945, May-September: Canadian Department of Agriculture-Agricultural Assistant Grade 11, Floristic and ecological surveys in the Maritime Provinces with special reference to pasture vegetation.
- 1946-1947: Ontario Agricultural College, Assistant Professor of Botany.
- 1947, 15 May: joined the staff at the Canadian Department of Agriculture and went on leave to complete Ph.D. studies.
- 1948, Ohio State University: Ph.D. in ecology.
- University Scholarship 1940/1941; University Fellowship 1942/1943.
- 1950, 1 July: permanent staff at Canadian Department of Agriculture
- 1956, Promoted to Senior Scientist
- 1976, 29 December: retired from Agriculture Canada.
- Professional Associations:*
- American Association for the Advancement of Science
- International Association of Plant Taxonomists (Charter Member)
- Canadian Botanical Association (Founding Member)
- Canadian Society of Technical Agriculturists, later called Canadian Society of Agronomy and Agriculture Institute of Canada (Charter Member)
- The Ottawa Field Naturalists' Club (Honourary Member)
- Nova Scotia Institute of Science (Associate Member)
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Appendix 3

A list of plants named in honour of W. G. Dore

× *Agroelymus dorei* Bowden, Canadian Journal of Botany 45: 715 (1967).

Festuca dorei Looman, Budd's Flora of the Canadian Prairie Provinces, 1st printing, Agriculture Canada Research Branch Publication 1662: 128 (1979). [illegitimate name]

Hieracium × *dorei* Lepage, Le Naturaliste canadien 94: 618 (1967).

Lolium dorei B. Boivin, Le Naturaliste canadien 94: 525 (1967).

Stipa nelsonii subspecies *dorei* Barkworth & Maze, Taxon 28: 623 (1979).

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Proposal to Establish a Chair in the Natural History of the Boreal Forest at the University of Manitoba

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Pruitt, William O., Jr. 1998. Proposal to establish a chair in the natural history of the boreal forest at the University of Manitoba. *Canadian Field-Naturalist* 112(2): 366–372.

The boreal forest, or taiga (Figure 1), extends in North America from the base of the Seward Peninsula in western Alaska in the United States, eastwards in Canada through the Yukon Territory, the southwestern parts of the Northwest Territories, the northern parts of the Prairie Provinces, narrows around James Bay, then extends across Quebec and Newfoundland (Rowe 1959). Over this distance of about 6200 kilometres it varies from 500 to 900 kilometres wide and occupies 17 percent of the land area of the continent. It exhibits several variants, such as the wet rain forest of the Pacific slopes of British Columbia, the spruce-fir-birch forest of northern Alberta, Saskatchewan, and Manitoba, the pines-hemlock forest of the northern watersheds of the Great Lakes, the pine and spruce of Quebec and the Maritime Provinces and the dense Black Spruce forest of Newfoundland (Shelford 1913; Shelford and Olson 1935). Even with these variants it is recognizable as a single type. In the early days of ecological classification it was known as the spruce-moose biome (Benton and Werner 1958; Shelford and Olson 1935).

Because the taiga, depending on its exact definition, encompasses between 25 and 40 percent of the land area of Canada there is great concern among taiga specialists about the long-term effects of changes to the forest and its animals. Unfortunately, the concern is unfocused; indeed, we know relatively little about the intricate operations of the taiga ecosystems. Some of the basic physical relationships of the climate and the trees have received recent attention; e.g., Project BOREAS (funded mainly by NASA), as well as studies by Forestry Canada (and others) on carbon storage (Krankina and Harmon 1994), but food webs, energy flow, population dynamics of vertebrates as well as invertebrates,

even distributions of some vertebrate species are known only sketchily. An important recent paper by Willson (1996) indicates the types of ecological processes and interactions that could be studied in future at Taiga Biological Station.

There are many threats to the integrity of the taiga ecosystems. Most publicity has focused on the clear-cutting of the West Coast rain forest and the mountain forests of British Columbia while threats to the rest of the taiga ecosystems are not generally recognized (Jardine 1994). There is, however, wide-spread loss of top carnivores, the Wolf (*Canis lupus*), the Wolverine (*Gulo gulo*) and, in the west, the Grizzly Bear (*Ursus arctos*). Populations of other species, such as White-tailed Deer (*Odocoileus virginianus*) and Moose (*Alces alces*), are distorted because of "management" for sports hunting. Populations of some species of carnivores are modified by management or by lack of control of "recreational trapping."

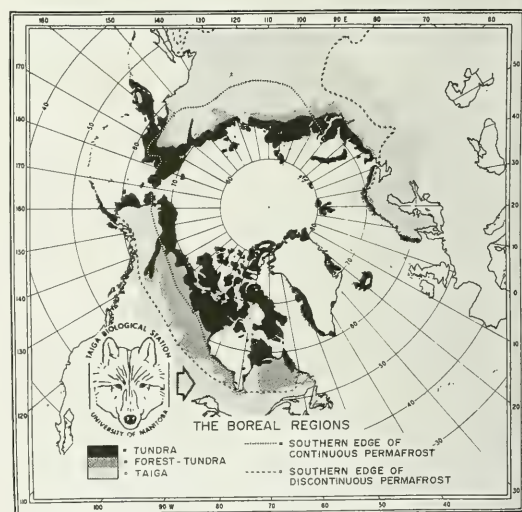


FIGURE 1. Map of the boreal regions showing location of Taiga Biological Station. At this scale boundaries are approximate. Adapted from Pruitt (1978).

Dr. Bill Pruitt has a long and distinguished career as a boreal biologist. He is an honorary member of The Ottawa Field-Naturalists' Club (see *Canadian Field-Naturalist* 111(3): 483 for a resumé of his career) and an associate editor of *The Canadian Field-Naturalist*.



FIGURE 2. Some reasearch activities at Taiga Biological Station. Upper Left: Glen Sutherland empties a subnivean trap that catches invertebrates active under the snowcover, in the background is a "trap chimney" (1980); Upper Right: "The Lab" in winter (1990); Lower Left: Richard Leonard uses a directional antenna to locate a radio-collared Fisher (1976); Lower Right: Mitch Campbell sampling vegetation in a study of Woodland Caribou (1985).

For one important species, Woodland Caribou (*Rangifer tarandus caribou*), there is widespread loss of the food base (lichens) because of clear-cutting and fires (Cumming and Beange 1993; Pruitt 1997). Sometimes the loss of this food base is not readily recognized, as when areas of lichens surviving after fire become unavailable and travel by Caribou impossible because of thick deadfall of fire-killed trees (Schaefer and Pruitt 1991). Over wide areas the vegetation has changed from ground lichens and arboreal lichens of the stable-aged forest to that of vegetation of pioneer and early successional stages. There is interference with populations of Wolves and Caribou because of roads associated with mining, pulping, and lumbering. In spite of our knowing we should not do it, extractive roads are still being pushed into wilderness areas (for example in the Woodland Caribou winter range of the Prairie Creek and Redrock Creek regions of Alberta and here in Manitoba an all-weather road on the east side of Lake Winnipeg to allow invasion of areas of Caribou winter range for clear-cutting). There is interference with Woodland Caribou fawning sites by tourist activities such as camping on critical points and islands.

The present distribution of taiga ecosystems across the continent is the result of about 10 000 years of development of soils and shuffling of plant and animal species and communities. The vegetation zones projected by Environment Canada that would result from doubling of atmospheric CO₂ show loss of most of the taiga with only isolated remnants surviving. Until we become much more familiar with the workings of the systems we cannot differentiate which human activities are really detrimental and which are more benign.

I began the Taiga Biological Station (TBS) in 1973 from donated materials and by volunteer labour. It is situated 5 kilometres from a road, accessible only by canoe, ski, or snowmobile, north of Wallace Lake, Manitoba, at 51°02'40" North Latitude, 95°20'40" West Longitude. Our past studies have concentrated on the area from Wallace Lake north to Aikens Lake and from the Ontario border west to the Broadleaf River and Leaf Lake. The area has been partly within and partly without Atikaki Provincial Wilderness Park, as the boundaries have been shifted by the Provincial Government. TBS consists of four log buildings with an inventory of scientific equipment (microscope, radiotelemetry materials, snow instruments, live traps, etc.) and bush equipment (skis, canoes, outboard motors, chainsaw, snowmobile, sleds, and so forth). We have also a small library of field guides, life history accounts and basic natural history books. Our most valuable asset is our location in a region that has a complete pre-contact mammal fauna, including Wolves, Wolverine, Fisher (*Martes pennanti*),

Woodland Caribou, and other species.

TBS is dedicated to the study of the animals and plants of the taiga in an undisturbed condition. We have produced a total of 52 graduate theses and scientific publications, such as studies of Woodland Caribou before and after fire, home ranges and inter-relationships of Marten (*Martes americana*) and Fisher with snow cover, effect of subnivean carbon dioxide accumulation on small mammals, ecology of Beavers (*Castor canadensis*) and Wolves, activity of invertebrates under snow cover, etc (See Bibliography of Theses and Research Publications from Taiga Biological Station). These studies have been supported by research grants from various agencies. Long-term support has been from the Taiga Biological Station Research Trust, administered by the Fort Whyte Foundation, which brings in enough funds each year to support a graduate student resident at the Station. I have calculated that Taiga Biological Station has brought in to the area somewhat more than a quarter of million dollars in research funds.

In 1977 we established a series of 6 one-acre study plots in a spectrum of vegetation types on which we have regularly sampled the populations of small mammals and vegetation recovery after fire. Dr. Karen Johnson, Curator of Botany at the Manitoba Museum, also has numerous study plots for her long-term research of vegetation recovery after fire.

The most important habitat changes to the research area were caused by a series of massive forest fires during the drought years of the 1980s. We have parleyed these disasters into research opportunities, so that all our studies now have a "burn recovery" component. Of course, all our studies also have a strong winter-ecology slant.

The time has come to repeat some of our earlier studies such as on Wolves, Woodland Caribou, and Mink (*Mustela vison*); to extend the work to include studies on Black Bears (*Ursus americanus*), Snowshoe Hares (*Lepus americanus*), and Lynx (*Lynx canadensis*). We need basic work on bogland and upland bog water relations. The extensive upland bogs are critical to survival of Woodland Caribou, yet we know very little about how they would be affected by ditching, draining, and pulping-cutting activities sometimes a number of kilometres away. Some of the small upland lakes have been leased to wild rice businesses which add biocides and fertilizers as well as change water levels by damming or by blasting channels through rock ridges. We have no idea how these changes affect water quality and supply to villages of aboriginal peoples downstream. We also need detailed delimitation of food webs, not only in the undisturbed forest but also how various intensities of cutting affect them. Because of our extensive data base I look on



FIGURE 3. Some teaching activities at Taiga Biological Station. Top: A class in Mammalogy studies the characteristics of a snowcover (1974); Middle Left: W. O. Pruitt watches a student measure the Density of a snowcover, the Boreal Ecology class participated in a long-term study of changes in snowcover characteristics in several habitats (1989); Middle Right: The TBS crest, embroidered black on yellow, use of the crest is limited to those who have actually spent time and worked at TBS; Bottom: Michelle Wheatley demonstrates radiotelemetry in her study of Beaver ecology to a group of volunteers from the Manitoba Naturalists Society (1992).

the Taiga Biological Station as a centre of research; we should become the focus of data collection, research, and monitoring for all the mid-continent taiga.

Our activities have not been restricted to research. A total of about 500 university students have participated in week-long field exercises, under frequently-rigorous conditions, which demonstrate aspects of mammalogy and boreal ecology. We have also given natural history labs at the primary school in the nearby village of Bissett and have hosted Natural History Days for such groups as Outward Bound, the Manitoba Wilderness Corps, and St. John's Ravenscourt School.

Continuity of the research and teaching is not assured, however. I retired from the University of Manitoba on 30 June 1996. I know that because of drastic reductions in University finances I will not be replaced. Such a situation would leave the Taiga Biological Station vulnerable to quick dissolution. I believe that the best way to ensure the safety, continuity and expansion of the existing data set is to establish at the University of Manitoba a Chair of Natural History of the Boreal Forest. Across Canada there are several Chairs concerned with aspects of the Boreal Forest. These are all, however, associated with exploitation (e.g., forestry, wildlife management). An endowed Chair such as I visualize would enable the occupant to attract outside funding so as to continue a planned, logical sequence of research at TBS. The program would ensure that topics of less popular or commercial appeal but great scientific implication would not be neglected because of lack of outside funds. Many of our studies have furnished basic data to guide regulatory agencies as well as users of boreal forest resources towards responsible activities. An endowed Chair would also ensure that the Department of Zoology could continue to offer such field-oriented courses as Mammalogy and Boreal Ecology. These courses are the incubators for future field scientists.

The Office of Private Funding of the University of Manitoba estimates that a fund of \$2 million is required to establish a fully-endowed Chair. They require a "lead gift" of about one-half this amount before they will launch a campaign. Now, University professors and field biologists, by their very nature, have little accumulated reserve to contribute to such a fund. What is needed are philanthropists who might be interested in supporting this proposal. I request each of you to distribute photocopies of this Proposal to potential sponsors.

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Book Reviews

ZOOLOGY

The Ecology, Status, and Conservation of Marine and Shoreline Birds of the Queen Charlotte Islands

Edited by Kees Vermeer and Ken H. Morgan. 1997.
Canadian Wildlife Service Occasional Paper Number 93.
Canadian Wildlife Service, Ottawa. 150 pages, illustrated.

King and Common Eiders of the Western Canadian Arctic

Edited by D. Lynn Dickson. 1997. Canadian Wildlife Service Occasional Paper Number 94. 75 pages.
Canadian Wildlife Service, Ottawa.

Both are available, free of charge, from Publications Unit, Canadian Wildlife Service, 4th floor, Place Vincent Massey Building, 350 St. Joseph Boulevard, Hull, Quebec K1A 0H3, Canada.

These two volumes are the latest products in the Occasional Papers series of the Canadian Wildlife Service: the major publishing outlet for science within the CWS. Material thus published complements other scientific literature by making available lengthy descriptive papers and reviews that are deemed to be important to the CWS, but which may not be of sufficient general interest to find a niche in regular science journals. Both of the offerings considered here meet these criteria, as they are largely descriptive and deal with topics generating current concern within the CWS: the conservation of birds in the Queen Charlotte Islands (Haida Gwaii) and the status of Pacific Eiders.

Turning first to Vermeer and Morgan's effort, this volume completes a set of three volumes, all masterminded by Kees Vermeer, that includes *The ecology and status of marine and shoreline birds of the Straits of Georgia* (1989, co-edited by R. W. Butler), and *The ecology, status and conservation of marine and shoreline birds of the West coast of Vancouver Island* (1992, co-edited by R. W. Butler and K. H. Morgan), both published by the CWS. Consequently, this volume can be viewed as Kees Vermeer's farewell to government publishing after a long career as a CWS research scientist (he retired in 1995). With the exception of three freelance biologists, and one university professor, all of the 20 authors involved work for the Federal Government.

In their introduction, the editors characterise the book as "a review of what is currently known about the marine biology of the Queen Charlotte Islands, with particular emphasis on birds." The first four chapters (47 pages) are devoted to physical and biological oceanography and all are authored by scientists based at the Pacific Biological Station,

Nanaimo, or the Institute of Ocean Sciences, Sidney: physical oceanography (W. R. Crawford), zooplankton (R. I. Perry, B. J. Waddell), invertebrate fisheries (N. F. Bourne), and marine fishes (G. E. Gillespie, S. J. Westrheim). They give a good overview of the physical systems and the consequent food webs on which the birds survive.

The meat of the book comes in Part 2, "nesting populations of marine birds and distribution of birds at sea", comprising a chapter on reproductive biology, status and conservation of seabirds (Vermeer, A. Harfenist, G. W. Kaiser, and D. N. Nettleship), and on the distribution and seasonality of marine birds (Morgan), together comprising 34 pages. This section is followed by two others including several short papers: on the distribution of brant (R. I. Goudie and M. Hearne), brant and sea ducks feeding on herring spawn (Vermeer, M. Bentley, Morgan, G. E. J. Smith), shorebird migration at Sandspit (Vermeer, M. Bentley, G. E. J. Smith), shorebirds breeding at Masset (J. M. Cooper and E. H. Miller), effects of introduced predators on seabirds (A. Harfenist and G. W. Kaiser), organochlorine contaminants in seabird eggs (J. E. Elliott, P. A. Martin, P. E. Whitehead), and concluding remarks by the editors.

Compared to areas further south, the marine and shoreline birds of the Queen Charlotte Islands are relatively poorly known. This probably accounts for the somewhat fragmentary nature of the bird accounts. In particular, the sea ducks, grebes, and loons, which form an important component of the winter and passage population of marine birds, are hardly dealt with, except in relation to herring spawning. Likewise, the shorebirds using North Beach, Rose Spit, and the beaches of eastern Graham Island, in winter and on passage, get little or no mention. Almost nothing is said of one of the Cahlottes' most familiar birds, the Black Oystercatcher. Treatment of conservation is also somewhat cursory, with only five pages devoted to the major problem of introduced predators, compared to ten on organochloride contamination: the latter no more than a distant possibility, as far as population level effects are concerned. Other important conservation issues,

such as the logging of Marbled Murrelet breeding habitat and the possible impact of marinas and other shoreline development, are mentioned but not enlarged on.

For anyone interested in the marine and shoreline birds of the Queen Charlotte Islands this will be a useful volume, though less comprehensive than its title suggests. The editors and contributors are somewhat pessimistic in their assessment of conservation needs, and it is always wise to be cautious, but it may be possible to be more optimistic now than when the volume went to press. Two of the major problems identified are being tackled with some success: rats have been eradicated from Langara Island (1996) and an ongoing collaboration between the CWS, the British Columbia Ministry of Environment, and Parks Canada seems to be halting the spread of Raccoons to seabird colonies. Things could get better, rather than worse for marine birds in the Queen Charlottes, and there are not many ecosystems in Canada for which we can say the same.

The volume edited by Lynne Dickson is narrower in its scope than the previous one, being an account of Common and King eiders in the western Arctic, with emphasis on migration, and population status. The compilation is a response to the recent dramatic declines of other Pacific eiders: Steller's and Spectacled, and a perception that we had insufficient knowledge of eider populations in Canada to know whether or not declines were taking place. Two papers deal with migration: a lengthy one by S. A. Alexander, Dickson, and S. E. Westover on spring migration in offshore areas and briefer one by R. Suydam and others on migration observed from Point Barrow, Alaska, which must be passed by all the Canadian western Arctic eiders twice a year in moving to and from their winter quarters in the Bering Sea and Northern Pacific. The last paper strongly suggests a dramatic decline in eider numbers over the past 40 years, from about a million in the 1970s to less than half that by 1994. This is followed by chapters on the breeding biology of

Common Eiders (B. J. Cornish, Dickson) and King Eiders (R. C. Cotter, Dickson, C. J. Gratto). The last gives a vivid illustration of why little is known about these birds' breeding: only 17 active nests were found in two seasons of field work by seven people — and this is a large bird that nests in completely open habitat! Current estimates of Common Eiders based on known breeding populations are far below numbers based on migration counts, so there is still much to be discovered about the Pacific race of Common Eiders, as well. The volume also includes a paper on King Eider activity budgets on the breeding grounds (A. C. Holcroft-Weerstra) and one on the subsistence harvest of eiders in the Inuvialuit land-claim settlement region (Banks and Victoria islands, and adjacent mainland; M. Fabijan and others). The latter suggests that about 2000-5000 eiders are harvested annually in the region, nearly all of them King Eiders, which are the more numerous species. The authors conclude that over harvest is unlikely to account for current population declines.

It is interesting to contrast the approach of the two volumes to conservation. In the Vermeer and Morgan volume, many potential conservation problems are identified, but only a limited amount of evidence is presented for actual population declines. In Dickson's work the population declines are very evident, but the causes are hardly mentioned because they are presently unknown and the authors seem disinclined to speculate. The eider volume is an important milestone in eider studies, but a combination of concern over population declines and the needs of the Nunavut land claim settlement seem destined to generate much new work on these species. We must hope that accelerated research activity will swiftly produce answers to the unsolved question of what has affected western eider populations.

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A Natural History of Amphibians

By Robert C. Stebbins and Nathan W. Cohen. 1995. Princeton University Press, Princeton, New Jersey. xvi + 316 pages, illustrated, U.S. \$19.95.

A increasing cascade of amphibian books has appeared through the last decade, and this fascinating group of vertebrates, encompassing such diverse life forms as the unfamiliar (to those in the temperate zones) caecilians, the somewhat more familiar salamanders, and the very familiar frogs, seems finally to be receiving the attention so justly due it for unique adaptations, impressive numbers, and ecological

importance. Unfortunately, the present emphasis owes most to recent awareness that we may be irretrievably losing many of them through the causes which we seem largely unable to adequately pinpoint. It is most likely that the reversal of present trends would demand sacrifices in terms of human population levels and lifestyle that enough of us will never be willing to make in time to benefit these animals.

Robert Stebbins and Nathan Cohen are impressive and most welcome contributors to this growing "amphibian decline" literature. Stebbins, long a pro-

fessor, and now an emeritus, of the University of California at Berkeley, is renown for his classic 1954 study of the complex circular geographic variation in the western terrestrial salamander *Ensatina eschscholtzi*, for his bench-mark texts on western North American amphibians and reptiles, which include the widely-used contribution for that region to the Peterson series published by Houghton Mifflin, for numerous outstanding graduate students, and for scientific papers on systematics, ecology, and behaviour of both amphibians and reptiles. He is, arguably, not just another good scientist, but one of the best amphibian illustrators in the world. His publications, and especially his guides, are widely recognized testaments to both his science and his art, and many familiar and new illustrations from his pen pepper this volume. Nathan Cohen is Emeritus Director of Curriculum Development in Science, University of California Extension, Berkeley, and widely admired for his crisp photographs of amphibians, such difficult subjects to light and keep still (though the black-and-white text reproductions here fail to do justice to his talent, the jacket ones reveal it effectively). The long association of these authors is indicated by their portrait together being from an expedition to the Galapagos Islands in 1964.

The book is an primer, skipping quickly through its topics, rarely dwelling more than a page, or at most two, on an individual heading. There are 18 chapters which organize our knowledge from a natural history

perspective: class content, skin, breathing, limbs and locomotion, tail, nose and chemoreception, eyes and vision, food habits, ears and hearing, voice, temperature characteristics, body water regulation, protection against predators, home range and movements, territorial behavior and fighting, homing and migration, reproduction, parental care. The penultimate chapter discusses the "Contribution of Amphibians to Human Welfare", covering food, teaching and research, toxicology and medicine. The final chapter, "Declining Amphibians", gives not just a crisp overview of what has been written on the topic and its possible causes but a strong statement on what it might reflect in terms of environmental health and the possible future of mankind. The book concludes with 47 pages of references, effectively skimming most pertinent of the classical together with an emphasis on the recent literature. Each section cites papers well selected to provide comprehensive original data on the topic summarized.

Overall, the book is an excellent topic reference for students, established researchers, naturalists, and communicators and should be on the bookshelves of each. Not only is it authoritative, but its price is among the most reasonable on the current market, where, too often, recent references seem priced primarily with limited sales to endowed university libraries in mind.

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A Birdwatching Guide to Southern Spain

By Malcolm Palmer. 1997. Arlequin Press, Chelmsford, Essex, England. 89 pages, illustrated £8.95.

This is a small, portable guide to help you find birds in the southern third of Spain. Starting at the southeastern corner, the most "African" part of Spain, the author takes us step by step to the borders of Portugal. Along the way he describes the key birding locations and the types of birds they offer. He does not clog the book with repetitive lists but describes the most interesting of local inhabitants. This book is written from a British perspective. If you have never been to Europe before, you will find the author largely ignores some spectacular species, like Kingfisher, because they are easily found elsewhere. The birds he does cover, rightly in my opinion, are those that are tough to see in other parts of Europe. These are an exciting mix of raptors, passerines, and coastal birds.

Each site or group of sites is accompanied by a set of directions and a small map. Both map and directions are clear. I think he should have included at least some road numbers on the map. Not a critical point, but it would help. A collection of practical

points follows each section. These cover everything from accommodation through crime (not a significant problem) to weather. The British viewpoint shows up in several ways. The author uses a few unexplained slang words — do you know what a "wellie" is? (a rubber boot). He makes comparisons that will baffle some — do you know what Merthyr Tydfil is like? Or even where it is? He refers to the areas huge size; Alberta alone is larger than all of Spain! He calls the fifteenth century the relatively recent past! The book is illustrated with black-and-white illustrations by John Busby. Busby is the king of quick-sketch artists. He used his long art experience and knowledge of birds to produce drawings that capture the "jizz" or attitude of his subjects. This style may not be to everyone's taste. Indeed his Little Egret sketch is very rough and ready. The author has included several coloured photographs of scenery. These introduce the reader to the variety of habitat found in southern Spain.

The author does not ignore Spain's rich cultural heritage. He mentions place, foods, festivals, and sites that only the most narrow minded of ardent

birders would ignore. Wisely he leaves the details of these delights to the standard tour guides.

This is a wonderful little book and I wish it had been available for my last visit to Spain. It has certainly whetted my appetite to return. It is small enough to slip in the glove compartment or even sit on the dash. It will lead you to the choicest of southern Spain's birds and you will reach spots where you can add the common species too. The appended specific species list and habitat guide will help here.

Two other items are appended; a "Rapid Guide" will allow you to assess your chance of seeing a rarity and a full checklist will let you track your success. In fact the checklist prompts my only suggestion for the author. I would like to have seen the Spanish names included in this list.

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Cranes: Their Biology, Husbandry, and Conservation

By David H. Ellis, George F. Gee, and Claire M. Mirande. Hancock House, Surrey, British Columbia 1996. 307 pages, 16 colour photographs, 118 black-and-white photographs, 16 maps, numerous sketches, charts and diagrams. \$69.95.

Cranes are among the largest and most stately of all birds. Yet this 15-species family is in jeopardy from human pressures and habitat loss, worldwide; ten of the 15 are declining in numbers, six of them are listed as Endangered and three more as Threatened. Species with the lowest numbers surviving are the Whooping Crane (324 individuals at time of publication), followed by the Red-crowned Crane (~1800 individuals) and Siberian Crane (~2900 individuals, with two of three populations nearly extirpated). Even the two most numerous species are not exempt from concern. Although the Sandhill Crane is the world's most abundant crane with an estimated half million individuals, it no longer breeds in many formerly occupied prairie marshes, and local populations centered on Mississippi and Cuba are listed as Endangered. The Demoiselle Crane of the Eurasian steppes, with over 200 000 individuals, ranks second in numbers, worldwide, but has endangered populations in North Africa and Turkey. Few bird families demonstrate better the need for worldwide habitat preservation.

The authors have responded to the obvious need for detailed information about avicultural science and husbandry, as specifically modified for cranes, with an extensive bibliography for each chapter. Sir Peter Scott wrote the foreword in 1988 only months

before he died, while the rest of the book took another eight years to complete. With 30 authors, a great deal of detailed and sometimes disparate information is provided. The first seven chapters deal mainly with technical topics concerned with the propagation of captive birds, while others deal specifically with artificial insemination, cryopreservation, sex determination, flight restraint, predator management, and reintroduction techniques.

I liked best the succinct presentation of each crane species, with detailed maps of breeding areas, wintering areas, and migration routes. A striking, full-page colour photograph illustrates each species. Attractive sketches are present throughout.

I detected no errors but found inconsistent terminology and ratings (e.g., "vulnerable", "threatened", and "endangered"), used in the text of Chapter 13 as compared to Table 1.3. Another four species, for a total of seven, are classed as Endangered by the International Union for the Conservation of Nature, and two of the five species classed as Vulnerable have endangered subspecies or populations.

This sumptuous book is highly recommended to anyone interested in propagation as a conservation method. Others would enjoy borrowing a library copy for an hour or two.

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The Hummingbirds of North America

By Paul A. Johnsgard. 1997. Second edition. Smithsonian Institution Press, Washington, D.C. xiii +278 pages, illustrated U.S.\$ 45.

A native South American name for these birds translates as "tresses of the day star." This is surely a more evocative term than the humble "hummingbird" and one that truly fits these wonderful, tiny

creatures. I used to prefer large birds with great flying skills, seabirds and raptors for example. I was happy to add Ruby-throated Hummingbird to my life list, but it remained just another tick until my first visit to Madera canyon, Arizona. This place is alive with hummers in summer and it will make a fan out of the most ardent raptor watcher. It did so to me.

Paul Johnsgard's book is actually a revised second edition and the author has expanded the number of species covered from 23 to 47. This represents about 15 percent of the total number of hummingbird species in the world. He has enlarged the geographic area covered to the Tenhuantepec isthmus (The narrow "waist" of Mexico) and thus added a number of Mexican species. While it is a scientific text written by an eminent biologist and author, it is so well written the non-scientist will have only minor difficulties in reading this book.

The author provides some fascinating information. For example, did you know that hummingbirds have the largest relative brain size of all birds? In fact the more you read the more you will be amazed by this group of birds. The author opens with chapters on classification, evolution, anatomy, ecology, behaviour, and reproduction. In these the author explains the marvels of hummingbird flight, the wonders of their feather colour and the bizarre life story of the nasal mite. I found the section on evolution particularly interesting, especially the apparent simultaneous adaptation of many plant species, along with the individual species of hummingbirds.

The species accounts are detailed and give biometrics, description, and habitat. I was more interested in the section on movements, behaviour, biology, and evolutionary relationships. The information on identification is particularly detailed and includes data that can be used to evaluate birds in the hand. The author pays specific attention to immature and female plumages. When describing foraging behaviour he identifies those plants that each species uses as its food source. It occurred to me that this information could be used to design a hummingbird-attracting garden. (Would it be possible to have sep-

arate areas for each species?) I will be looking for both Calliope and Rufous hummingbirds next May as I explore the Rocky Mountains. I am anxious to see, if I can, the courtship flights of these two little gems. Maybe I will even find a nest or two! Certainly, with the help of Johnsgard's book, I am better informed about what specific habitat to look for and where to search. This book provides a solid background for the North American birder. It will be most useful to people in the south west, but also provides a fine reference for birders everywhere.

There is a colour plate section between the preface and the main text. This is not an arrangement that appeals to me. About forty of the species are represented in "artistic" plates of mostly males flying around an appropriate flower. These are accurately illustrated and "suitable for framing" — although you would never catch me cutting them out of my book! Then follows four field-guide style plates taken from *A Guide to the Birds of Mexico and Northern Central America*. While this allows the author to illustrate the additional species and females of those males depicted earlier, for my taste it is an incongruous mix. Each species account has a map showing species breeding range, migration routes, wintering and resident areas. While clear, they look as if they were made using "letraset" rather than a modern computer method. This has resulted in some inconsistencies in shading keys so you must read the legend on each map. The black-and-white illustrations that dot the species accounts and other parts of the text are well crafted and serve to illustrate the key points.

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The Galápagos Tortoises: Nomenclatural and Survival Status

By Peter C. H. Pritchard. 1996. Chelonian Research Monographs, Number 1: 1-85, illustrated. Chelonian Research Foundation, 168 Goodrich St., Lunenburg, Massachusetts 01462. Cloth U.S. \$29.00; paper U.S. \$19.00; plus U.S. \$3.00 postage.

The biota of the Galápagos Islands, an archipelago of small, volcanic islands in the Pacific Ocean, has long fascinated naturalists. Along with Darwin's finches and marine iguanas, the Galápagos tortoises are probably the most famous inhabitants of these islands. With shells over a metre long and weighing upwards of 250 kilograms, these giants are known from or suspected to have occurred on 11 of the largest islands in the archipelago. These tortoises have long been threatened by humans and despite largely successful attempts in the last few decades to replenish wild stocks, recent developments on the

Galápagos Islands suggest that the continued survival of wild populations is not assured. *The Galápagos Tortoises: Nomenclatural and Survival Status*, by noted cheloniologist P. C. H. Pritchard, is the first major work in several decades on these tortoises.

The main body of this book is divided into three major sections. The first of these, "Historical Overview," highlights the published literature on Galápagos tortoises, and is divided into four concise accounts summarizing the chronological development of scientific interest in these tortoises: discovery and early observations (1535-1840); early taxonomic studies (1824-1917); relocation of individuals to mainland zoos, where captive breeding programs were established (1925-1955); and implementation of conservation strategies on the Galápagos Islands to ensure the survival of native populations (1957-present).

In the second section, "Nomenclatural Status," we once again are reminded that the nomenclature and taxonomy of the Galápagos tortoises are confused. Part of this ongoing confusion has to do with practical difficulties in identifying different taxa of Galápagos tortoises, which historically have been differentiated largely by subtle differences in their shell morphologies. Unfortunately, shells of Galápagos tortoises — and many other turtles as well — are prone to rampant sexual, ontogenetic, individual, and ecological variation, which conspire to mask or mimic taxonomically significant features. Such difficulties are compounded by other problems, for example: the islands from which some critical specimens originated are unknown, while other specimens may have been collected from islands onto which they had been introduced; several taxa lack adequate reference collections; and at least six taxa are extinct and, thus, can no longer be sampled. The other major problem with the Galápagos tortoise complex is more philosophical: namely, whether the different island populations each represent a distinct species or are subspecies of a single species. Pritchard does a generally adequate job of discussing these problems and the nomenclatural headaches they have generated, although in a less organized fashion than I would have liked. He then proposes a new classification for the Galápagos tortoises, in which he recognizes ten named (seven extant) and four unnamed (one extant) subspecies of *Geochelone* (*Chelonoides*) *nigra*. Of these, only two of the unnamed, extinct subspecies are not figured. Having proposed a new classification for the Galápagos tortoises, one that differs somewhat from schemes presented in the recent past by himself (Pritchard 1979) and others (e.g., Ernst and Barbour 1989), it would have been nice if Pritchard had provided diagnoses for his recognized subspecies and commented on their possible relationships. On a more positive note, I was pleased that Pritchard concluded this section with a warning to those who sneer at taxonomic work by noting that when a taxon is unnamed, as in the case of the unnamed subspecies of Galápagos tortoise from northwestern Chatham Island, it typically does not exist in the eyes of the law and, hence, rarely receives the legal protection that may be afforded to named taxa.

The last section, "Survival Status," documents the history, current status, and future prospects of extant and extinct populations of Galápagos tortoises. The good news is that although human activities have adversely affected all tortoise populations, a few surviving populations currently are robust and appear healthy. A poignant example of a soon to be extinct subspecies is provided by "Lonesome George," probably the last known surviving tortoise from a once thriving population on Abington Island. This popula-

tion and most others were hunted for food until the late nineteenth century, largely by sailors who between 1831 and 1868 harvested at least 13 000 tortoises, and then later by settlers for the oil that was extracted from the tortoises' flesh. This unchecked exploitation certainly contributed to the decline and collapse of many populations, but no less disastrous has been the introduction of feral mammals that disturb nests, eat eggs and hatchlings, and strip islands of much of their vegetation. Until reading this book, I was under the mistaken impression that conservation efforts — such as captive breeding programs, captive rearing of hatchlings, and the establishment of the Galápagos National Park — over the last few decades had saved the Galápagos tortoises. Unfortunately, problems with feral mammals and poaching continue, and in recent years the human population has swelled with immigrants hoping to benefit from the eco-tourist boom that has assaulted the islands. Settlers who cannot find work in the lucrative tourist trade turn to fishing and agriculture — not always of the legal variety — which leads to conflict with conservationists. Such conflicts have degenerated to the extent where wild tortoises have been killed, both for food and apparently revenge, and settlers have threatened to slaughter tortoises in captive breeding programs. Hopefully, calmer heads will prevail and an accommodation between tortoises and settlers will be reached. If not, the only chance we may have to see living Galápagos tortoises will be in zoos.

This is a handsome volume: it is printed on glossy paper and contains few typographical errors. Pritchard's enthusiasm for these tortoises is evident in his text, which is complemented by 10 maps and 58 high quality photographs, most of which are in color. Of historical interest are reprints of five older black-and-white photographs, the value of which is enhanced by the inclusion of their original captions. The publication list is up to date and extensive, consisting of 242 references.

The Galápagos Tortoises is not the definitive work on these tortoises, but I suspect this was not Pritchard's intention. Instead, it is a timely and generally satisfactory account of these animals at a potentially critical juncture in their history.

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ENVIRONMENT

People and Environment

Edited by Stephen Morse and Michael Stocking. University of British Columbia Press, Vancouver. 215 pages, illustrated. \$24.95.

Along with other faculty at the University of East Anglia, Stephen Morse and Michael Stocking hold a series of lectures every winter on topics of environmental concern. This book is a compilation of the 1990 lecture series, edited and expanded into book form. After the 1992 "Earth Summit" in Rio de Janeiro additional material was inserted and the resulting book was published in 1995 by the University College of London Press. The current edition by UBC Press was printed in Canada in 1996.

The book is an attempt to educate people on environmental issues such as sustainable development, global warming and the greenhouse effect, and on gender issues and their cultural impact in different parts of the world. Finally it contains an essay dealing with the effect of rapidly expanding human population in relation to population controls already in place, and dealing also with questions of how future controls or lack of controls might impact on the world. The book does not try to be totally comprehensive — it is, after all, a publication of a series of lectures — but there is much food for thought in the presentations.

Political ecology is a term which the first writer, Piers Blaikie, coins to explain the relationship between the concerns of environmentalists and the societies in which they live. In essence, an environmental topic is only relevant to a group of people if they choose to make it so. An environmental topic which is imposed on a group of people who do not wish to consider it, will not get any political support or action. As if in response to this thesis, the topics presented in the book are all of interest to politically minded academics and students. Politically correct positions might be a better way of describing the choice of topics included, though the studies each have merit of their own. The "Earth Summit", The United Nations Conference on Environment and Development in Rio de Janeiro in July of 1992, was a political gathering but the outcomes were generally positive emphasizing human needs and the implicit subservience of nature. Political decisions did play

an important part in the outcome of the conference and the book illustrates such events, for example the U.S. President George Bush's refusal to sign the framework Convention on Biodiversity, in case it might impact negatively on the economy of the United States. Other northern economies also have shown much political protectionism where conservation of industrial initiatives in their countries came to question.

The greatest dichotomy between state rights and individual rights exists in the last chapter of the book. Here the authors present doom-and-gloom statistics about world overpopulation, but without commenting on the ethical implications for individual rights. Initiatives for the reduction of population growth are praised by the authors even where nations with reduced birthrate statistics include the practice of inducing high mortality and low fertility into their populations. This manipulation of human population can only be accomplished at the expense of human rights, a topic which has to be addressed in any discussion of environment and development. The essay on Environmental Reproduction and Gender steers clear of comment on over-population and gender issues inherent in such a discussion of personal freedom.

Coexistence with the natural world is the bottom line for the studies of this book. In each topic, the status of human impact on the natural world is at issue and even the language of development has to be considered when the preservation of nature is at issue. Human populations need various resources and in order for the quality of life to be maintained or enhanced, the world's resources will be exploited. In order wisely to use and to share the resources available in the world, we need constantly to assess and to limit our consumption. This book is an attempt to bring these limitations in line with our consciences.

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Deeper Ecology: Essays On Ecological Spirituality

By David Andrew Doyle. 1996. Wild Side Publishing, Eureka, California. 47 pages, U.S.\$6.95 +U.S.\$13 foreign shipping.

This collection of brief, loosely related articles purports to introduce a new school of thought, deeper ecology, which, as the author explains in the auto-

biographical sketch at the end of the work, "is much like the environmental ethic deep ecology ... the only difference being that I go a step beyond the current ideology of preservation, and add a spiritual element" The claim is more extravagant than the reality.

The concept of deeper ecology, introduced about half-way through the text after a section on the need for simpler living, is described as "a synthesis of what the Native American Indians and Buddhist and Taoists were trying to accomplish." "With these three disciplines", the author continues, "I shed a light of science and biology into the grand scheme of cosmic, inter-related metaphysics . . ."

In the concluding essay the author further clarifies his purpose under two points. The first is that this work is his "will and testament to the earth, and to all of the creatures which embrace it's sustenance". The second is that it serves "as a will and testament that I leave to all generations of *Homo sapiens* to come, as a warning and a lesson, and as a profound guideline and protocol for the insurance of a universal home (which is the definition of ecology) for us all; . . ."

A passionate naturalist with a keen sense of earth's beauty and a deep appreciation of non-human species, he does a credible job of his testament to the earth and its creatures. Deep ecologists will approve of his arguments against "anthropocentrism", and of his celebration of the worth of other species. Some of the most appealing essays are those in which he relates, with feeling, his experiences with wild creatures in natural settings. As to the will and testament

— unburdened by humility — which he leaves to future generations, I have difficulty thinking that it is either particularly unique, or as spiritually advanced as he claims.

The author finds deep spiritual meaning in the natural world: "This is my church, my religion, my sanctuary." He believes in creation by evolution. He views the God of every religion as a figment of imagination but doesn't deny or renounce God. "Darwin and God are the perfect synthesis of all I know to be true", he declares then adds, "I bring to these two ideologies the third component of wholeness that a perfect being can attain: Deeper Ecology". I find little in the collection of essays to justify such an immodest claim. There are many who find profound spiritual meaning in the natural world, deep ecologists included. There are many who believe creation takes place by evolution. While I resonate with the author's love of the natural world, and affirm his emphasis on its innate worth, I search in vain to find the evidence that would lead me to think of *Deeper Ecology* as the third member of the Trinity.

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The Abstract Wild

By Jack Turner. 1996. The University of Arizona Press, Tucson. xvii + 136 pages. Cloth U.S.\$32.50; paper U.S.\$15.95.

Jack Turner is a mountaineer, world traveller and climbing guide in Grand Teton National Park. In the course of his travels he has taken a lot of time to look at the world, a vision which he shares in this book telling of his perception of nature, the wilderness as it exists today and the direction which wild lands, animals and people are taking today. His second chapter is entitled "The Abstract Wild: A Rant" and it is written in the tone of outrage and cynicism with which he approaches most of the policy-making attitudes adopted towards the natural world today. Animals and humans alike are cheated in the fallout from disappearing and managed natural areas. Anything managed is not wild and a managed wilderness area is an oxymoron.

The book is a collection of Turner's experiences as a traveller and observer of wildlife, together with frequent references to natural philosophers, reflecting Turner's own studies and experience as a philosopher. Thoreau, Aldo Leopold, Gary Snyder, and other contemporary writers are all represented in his arguments, with their wisdom and their perspectives on the nature of their time. Thoreau spoke out in cynical terms in his day against the economy

which people valued and elevated above relationships. Turner speaks his outrage today at economists and industrialists who classify natural areas in terms of economic benefits, citing a resource like a forest in terms of board-feet of lumber, or marketing a parkland in terms of tourist dollars generated to support the local economy. The "fun factor" involved in selling tourism in wilderness areas is as intrusive in a natural setting as forest clearcutting or mining.

Turner's writing style is anecdotal and profane. His intent is to express outrage and he does so with reverence for nature and the sense of the wild which is passing from our midst. His remarks are also separated from any religious belief system, a point which he makes clear by giving a history of his spiritual quests. Therefore, he comes to rest in the "manifestations of a life committed to walking the ground and trusting stone — rock bottom and solid" as his friend and fellow writer Terry Tempest Williams writes on the rear cover of the book. We also can be outraged and encouraged at the same time to follow the footsteps of one who can see the wild things of the earth hunted, appreciated and even feared, as we look to a wild world which has disappeared except in the abstract descriptions of promotional brochures. I liked the book and lamented with Turner that the wild which I

have experienced has always been tamed by someone else long before I visited it. All my wanderings have been along beaten tracks and the areas which I now explore are described in guide books and can be previewed from the comfort of my armchair.

The Abstract Wild is provocative reading and the reader is not expected nor encouraged to be always in agreement. I read it in a couple of sittings and have been pleased to discuss the contents with several college students as well as handing it around for them to read. I think that his questions are timely and

the opportunity to present this material to people who appreciate nature is almost past. Whatever our attitudes toward nature, neglecting to be informed, and outraged in the face of exploitative actions is our own fault. Jack Turner's book is designed to arouse in us in a healthy attitude of outrage.

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The Work of Nature: How the Diversity of Life Sustains Us

By Yvonne Baskin. 1997. Island Press, Washington, D.C. 263 pages, illustrated. U.S.\$25.

With continued loss of biodiversity through continued expansion of human endeavors to simplify wildlands for use as agricultural lands often with monoculture production techniques, and conversion of forests to simplified tree plantations of a few economically important species; the human race needs to consider the costs. With this in mind the Scientific Committee on Problems of the Environment (SCOPE) commissioned *The Work of Nature* to answer the question "What are the possible consequences of the accelerating losses in biodiversity?" Yvonne Baskin was to provide a translation of the scientific document into a form accessible to a general reader.

The book was organized into nine chapters covering such topics as the web of life, keystone species theory, ecosystem communities, the effect of manipulations, the importance of climate, atmosphere, water, soil, and plants. Each chapter was provided several case studies to aid in describing the concepts. The book was not meant as a review and therefore does not come with an extensive reference

listing. But the reader was provided enough references to obtain more detail or expand the knowledge base in the area.

The overwhelming message was: a great deal more understanding of the world on which humanity depends is required. The few attempts mankind has made to manipulate systems have resulted in, at best, less than desirable results often with large unexpected costs. The diversity of life surrounding us all has a purpose but we are only just beginning to understand its benefits. The benefits are often discovered after the web of life has been disrupted.

This reader was provided a book well organized, easy to read and hard to put down. *The Work of Nature* can be recommended for the general reader and the technically trained. Both will benefit from the contents. Yvonne Baskin is to be congratulated for her ability to translate highly technical information into such a readable form.

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Small Islands, Big Issues: Sustainable Development of Islands

By Counterpart. 1997. Counterpart International, Washington. 141 pages, illustrated. U.S.\$28.

Sustainable development in island nations is influenced by a range of issues and problems as unique as the natural heritage they possess. These determining issues include their small size and vulnerability to natural disasters, ecological fragility, and economic disadvantages. Increasingly, the long-term sustainable prognosis for these island nations is being determined by global forces beyond their control (i.e., climate change).

Small Islands, Big Issues: Sustainable Development of Islands summarizes the results of the Barbados Declaration and Programme of Action

for the Sustainable Development of Small Island Developing States. This meeting was held in Bridgetown, Barbados, in 1994, under the auspices of the Alliance of Small Island States (AOSIS). The document itself is divided into two parts: a section detailing a plan of action for sustainable development and a section providing brief data sketches of AOSIS-member states.

The plan of action is structured according to such environmental issues as climate change, management of wastes, natural and environmental disasters, national institutions and capacity, as well as by important resources (e.g., land resources, energy, tourism, and biodiversity). Specifically, the plan of

action provided in the document covers three broad areas: management of environmental problems; management of vital natural resources; and, the human resources and institutional requirements for sustainable development. Within each section, an introductory preamble is followed by a list of policy and project actions required, disaggregated according to national, regional and international priorities. As a result, *Small Islands, Big Issues* provides an informative summary of the issues and a corresponding set of required implementation-oriented activities, as well as the section summarizing socioeconomic data for the different islands. While the benefits of this latter section are not evident, nor linked in a meaningful way to the rest of the document, the summary of issues and associated description of needed actions is addressed in adequate detail.

The comprehensive list of activities set forth is useful for policy makers and planners charged with responsibilities for sustainable environmental and economic development in small islands states. As well, they will inform those managing bilateral and multilateral programmes and projects which influence the development of these unique nations. Additionally, *Small Islands, Big Issues* could also be useful to researchers looking to set their specific activities within a valuable framework of action. However, many of the activities identified are dependent upon traditional financing through cash-strapped government departments and agencies.

Less emphasis appears to have been placed on establishing alternative funding sources and financing arrangements than on developing a comprehensive set of activities. The implications of this on action plan implementation will likely be significant.

While *Small Islands, Big Issues* does place proposed activities within the context of other international agreements and framework accords relating to environmental and economic issues, several of the action items are all-encompassing and unwieldy. This makes monitoring of progress more difficult. However, follow-up to proposed activities and actions is essential to monitoring and, therefore, to determining progress towards sustainable development. As well, it provides important political material for ensuring things get done where activities have failed, and promoting positive local, regional and international actions that have contributed to sustainable development.

Despite the fact that it was published three years after the Bridgetown meeting, *Small Islands, Big Issues: Sustainable Development of Islands* is an important contribution. And while many of the proposed actions may be difficult to monitor, even unattainable in some cases, it provides a useful framework to promote and chart the progress of island states towards sustainable development.

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The Food Web of a Tropical Rain Forest

Edited by Douglas P. Reagan and Robert B. Waide. 1996. The University of Chicago Press, Chicago. 616 pages, illustrated. Cloth U.S.\$110; paper U.S.\$39.95.

The patterns of connections among species based on what they consume and what they are consumed by forms the food web. Even simple ecosystems can have complex webs, and consequently most studies have been in relatively simple environments. *The Food Web of a Tropical Rain Forest* takes a first step toward exploring the architecture supporting one of the most complex ecosystems in the world.

By tropical standards, this Puerto Rican rain forest is a simple ecosystem; there are, for instance, fewer species of moths and butterflies in the study area than there are in New York State. Yet this simplicity allows a study of this rigour to be conducted. With contributions by 16 authors, the book summarizes 35 years of research in a 40 ha section of a tabunoco rain forest. Of the 14 chapters, 11 are devoted to different taxonomic groups, 2 are overviews, and one, I was pleased to see, is devoted to stream communities. Each chapter begins with a description of the

taxa, the number of species, and estimates of abundance (population densities, biomass) before moving onto feeding behaviour, energetics, trophic relationships (as predators and prey for other species), and the energy and nutrient cycles. Large tables listing the species are provided, and the start of each chapter has a schematic diagram of the same simplified food web of the whole ecosystem with the taxa in question highlighted.

This book reveals some interesting results central to food web theory. For instance, it has long been assumed that feeding loops, where one species feeds on itself, or is fed on by a species that it consumes (often at different life stages), are supposed to be rare, yet in this ecosystem they are surprisingly common. Points such as these make this a very interesting book for ecologists studying tropical rain forest ecosystems or food web dynamics in general.

This is definitely not a book for the lay-audience, however, and it would likely prove disappointing to many ecologists. Because taxa are treated separately, the book gives a false sense of segregation of the

food web, and leads to a great deal of repetition, as any link in the web is discussed from the perspective of the different taxa. It was frustratingly not possible to visualize the different organisms, as there are very few photographs (all of poor quality), and no descriptive illustrations to help the reader unfamiliar with this ecosystem. Surprisingly disappointing are the food web diagrams. Each chapter is preceded by the same, simplified drawing with the compartments for the taxa being discussed highlighted. It would have been better to "zoom in" on the feeding relationship being discussed to detail the nature of the interactions. Other, non-dietary interactions, such as commensalism, parasitism, shelter, and competition would also be worthy of treatment of their own, as

would more discussion of conservation issues. But given that the book already has 488 pages of text, there is little room for more information.

This is an excellent, rigorous summary of studies in one tropical rain forest, and is therefore an excellent resource for someone already studying food webs or rain forests. However, it is not recommended for readers with anything less than academic interests in these areas. Ironically, *The Food Web of a Tropical Rain Forest* makes for a very dry read.

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The Marshes of Southwestern Lake Erie

By L. W. Campbell. 1995. Ohio University Press, Athens, Ohio. 233 pages, illustrated.

The public's perception of wetlands in the southern Great Lakes region has changed since the arrival of the first settlers from Europe. The early settlers regarded wetlands as obstacles to development and economic prosperity, a view that largely persisted to the 1960s. Consequently, wetlands were drained and converted to other land uses. From the 1960s and into the early 1980s, the importance of wetlands shifted with the realization that wetlands have positive attributes. Major conservation campaigns were initiated to protect wetlands from continued destruction. In the past decade or so, a much more informed and educated society has improved knowledge and scientific understanding of wetlands and their value to society in both a natural and managed state.

The Marshes of Southwestern Lake Erie is an eye-witness historical account by Mr. Campbell, who writes this book at 95 years of age, of wetland change. He has experienced first-hand how the public's perception of wetlands has changed since his youth in the 1920s. He focuses on the coastal marshes on Lake Erie in Ohio. The book consists of two parts. The first part is an almanac of one year in the life of a Lake Erie coastal marsh. It is an account of personal observations on the mysteries, beauty, puzzles, and biological intricacies of a marsh through four seasons. His essays are most lucid and easy to read, and are a fine testament to the powers of observation. It is not hard to imagine oneself in the marsh. Readers will realize there is life in a marsh the year round. I found his account of the marsh during the winter and late autumn particularly fun to read.

The second part of the book is a more scientific

account written for the lay person on the history of Lake Erie coastal marshes from the time of glaciation to the present. It is a more detailed account of how the marshes originated and formed in response to changing water levels, and why and how humans in recent centuries have altered and destroyed them. This is accompanied by a series of geological and archival maps. This section ends with summaries of the efforts to seek protection for several key marshes in the Ohio area. His intentions are to encourage others to continue these efforts.

I am sure readers will find the historical data on wildlife most interesting. He reports, for example, information on the number of birds shot in the 1890s in one marsh and notes the scarcity of Canada geese at that time compared to their abundance in the marshes today. Further, he lists several mammal species and the years they are thought to have disappeared and those species which disappeared but reappeared in the region some decades later.

This is an interesting book of one naturalist's experiences in the Lake Erie marshes. It illustrates how sensitive to change and how resilient to change these wetlands are. One message to come through loud and clear is the realization of the degree to which some of the most intact marshes today have been changed by humans and how different they are compared to their condition prior to the time of early land settlers. This book is fun to read and I have no hesitation in recommending it for your bedside table.

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MISCELLANEOUS

Privileged Hands, A Scientific Life

By Geraat Vermeij. 1997. W. H. Freeman and Company, New York. 297 pages, illustrated.

Autobiographies are meant to set the record straight, correct our ignorance of one's life, provide a pulpit to which to express oneself on related matters, but most of all, an autobiography should, when possible, inspire. *Privileged Hands*, the autobiography of Geraat Vermeij, is one such book.

Vermeij is a biologist specializing in invertebrates past and present, and currently working out of the University of California, Davis, who has been denied his sense of sight since early childhood. "Denied" is probably not an appropriate word because Vermeij does not think so. His senses of touch, his analytical approach, and poetic prose are what are collectively unique and not just his blindness. I cannot find another passage in contemporary science that can approach his: "Far above my head, on a densely wooded island, a concert of soprano cicadas is in progress, each insect singing fast little arpeggios like a miniature fire engine siren in the blazing sun. The double tones of a bellbird, hauntingly pure and distant echo among the trees and rock walls, ... the luxuriant rain forest above touches a magnificent coral reef below, and I am fortunate enough to be in their embrace" (page 171).

His blindness is an issue for Vermeij, not in its seemingly limiting parameters for himself, but in his relationships with the establishments of societal "norms." "Preconceptions about the abilities of the blind are widespread, and only dispassionate and unfrontational presentation of evidence face to face, together with a reasonable self confidence, can overcome such prejudices in people with an open mind" (page 81). In the face of such prejudices his obvious encounters with ocean research on remote

islands and terrestrial field work tracking down limpets near the shores of Guam, for example, ("Guam was love at first feel", page 86) are entertaining and enlightening, even if you are not a fan of the invertebrate world.

Littered throughout the text is his passion for learning and most intriguing is his perceptions of the act and atmosphere of the scientific activity. As author of numerous scientific papers and at separate times editor of *Paleobiology* and *Evolution*. Vermeij condemns the "adversarial ethic" when differing views are apparent, while cooperative efforts are encouraged on such grand issues of evolutionary mechanisms. Or, the simple ability of sitting in a university department's coffee room where students and professors can chat comfortably and freely about a diversity of topics, "contribut[ing] immeasurably to the intellectual health of academic departments" (page 93).

His growth, from his detailed examination of individual invertebrate taxa from selective sites to their role in the more global scene, in combination with appreciation of wider evolutionary meaning, is the skeleton of *Privileged Hands*. But first and foremost, this book is an illustration of his passion for learning. "There is so much scope in science, so much freedom to explore and to work, that scientists can bring to their disciplines the same individuality, the same personal signature, that novelists and painters bring to theirs" (page 244).

Privileged Hands is inspiring for anyone taking their first steps towards the scientific arena and may rejuvenate a few who may have lost a little bit of why they first made those steps.

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NEW TITLES

Zoology

***The American pronghorn: social adaptations and the ghosts of predators past.** 1998. By J. A. Byers. University of Chicago Press, Chicago. xviii + 310 pp., illus. Cloth U.S. \$70, paper U.S. \$ 23.95.

***Amphibians in decline: Canadian studies of a global problem.** 1997. Edited by D. M. Green. Society for the Study of Amphibians and Reptiles, Biology Department, St. Louis University, St. Louis, Missouri. xiii + 338 pp., illus. U.S. \$39; Cdn. \$55.

***Ancient marine reptiles.** 1997. Edited by J. M. Callaway and E. L. Nicholls. Academic Press, Orlando. xvi + 502 pp., illus. U.S. \$64.95.

Animal intelligence: why is this dolphin smiling. 1998. By E. Pascoe. Blackbirch Press, Woodbridge, Connecticut. 48 pp., illus. U.S. \$16.95.

†**Animal tracks of Ontario.** 1997. By I. Sheldon. Lone Pine, Edmonton. 160 pp., illus. \$7.95.

†**Behavior and ecology of the northern fur seal.** 1997. By R. L. Gentry. xiii + 392 pp., illus. U.S. \$ 69.50.

***The biology of sea turtles.** 1997. By P. L. Lutz and J. A. Musik. CRC Press, Boca Raton, Florida. 448 pp., illus. U.S. \$79.95.

***The bird collectors.** 1998. By B. and R. Mearns. Academic Press, San Diego. xviii + 472 pp., illus. U.S. \$29.95.

Brown trout. 1997. By N. Karas. Lyons and Burford, New York. ix + 371 pp., illus. U.S. \$35.

***The butterflies of Canada.** 1998. By R. A. Layberry, P. W. Hall, and J. D. Lafontaine. University of Toronto Press, Toronto. c376pp., illus. Cloth \$75; paper \$29.95.

The butterflies of Papua New Guinea: their systematics and biology. 1997. By M. Parsons. Academic Press, Orlando. c800 pp., illus. U.S. \$275.

Discovering birds: the emergence of ornithology as a scientific discipline, 1769-1850. By P. L. Farber. Johns Hopkins University Press, Baltimore. xxiii + 191pp., illus. U.S. \$14.95.

***Ecology and management of the North American Moose.** 1998. Edited by A. W. Franzmann and C. C. Schwartz. Smithsonian Institution Press, Washington. xxvi + 733 pp., illus. + plates. U.S. \$59.95.

Freshwater fishes. 1997. By E. C. Beckham and J. Sherrod. Peterson Flashguides. Houghton Mifflin, Boston. 24 panels, illus. U.S. \$7.95.

†**A guide to the nests, eggs, and nestlings of North American birds.** 1997. By P. J. Baicich and C. J. O. Harrison. Academic Press (Harcourt Brace) Sidcup, Kent, United Kingdom. 347 pp., illus. + 64 plates. U. S. \$24.95.

Hawk highway in the sky: watching raptor migration. 1997. By C. Arnold. Gulliver Green, San Diego. 48 pp., illus. U.S. \$8.

Last of the wild: vanished and vanishing giants of the animal world. 1997. By R. M. McClung. Linnet Books, New Haven, Connecticut. xi + 291 pp., illus. U.S. \$27.50.

†**The raptors of Arizona.** 1998. Edited by R. L. Glinski. University Arizona Press, Tuscon. 288 pp., illus. U.S. \$75.

Sea slugs of Atlantic Canada and the Gulf of Maine. 1996. By J. S. Bleakney. Nimbus, Halifax. 216 pp., illus.

†**Shorebird migration and staging at a large prairie lake and wetland complex: the Quill Lakes, Saskatchewan.** 1997. By S. A. Alexander and C. L. Gratto-Trevor. Occasional Paper No. 97. Canadian Wildlife Service, Ottawa. 47 pp., illus.

†**Working for wildlife: the beginning of preservation in Canada.** 1998. By J. Foster. 2nd edition. University of Toronto Press, Toronto. c300 pp., \$21.95.

Botany

†**Agaves of continental North America.** 1998. By H. S. Gentry. University Arizona Press., Tuscon. 670 pp., illus. U.S. \$110.

American arctic lichens: 2. the micro lichens. 1998. By J. W. Thomson. 674 pp., illus. U. S. \$100. (limited edition).

Biodiversity and classification of flowering plants. 1997. By A. Takhtajan. Columbia University Press, New York. x + 643 pp., illus. U.S. \$95.

***Plants of Kanaskis.** 1997. By C. C. Chinnappa and B. Hallworth. University of Alberta Press (distributed by University of British Columbia Press, Vancouver). lxiv + 368 pp., illus. \$19.95.

†**Dune county: a naturalist's look at the plant life of the southwestern sand dunes.** 1998. By J. E. Bowers. Uni-

versity of Arizona Press, Tuscon. 156 pp., illus. U.S. \$15.95.

***The ferns and allied plants of New England.** 1997. By A. E. Tryon and R. C. Moran. Massachusetts Audubon Society, Lincoln. xiv + 325 pp., illus. U.S. \$49.95.

In the company of mushrooms. 1997. By E. Schaechter. Harvard University Press, Cambridge, Massachusetts. xvi + 280 pp., illus. U.S. \$24.95.

†**Plant life histories: ecology, phylogeny, and evolution.** 1997. Edited by J. Silvertown, M. Franco, and J. L. Harper. Cambridge University Press, New York. xviii + 312 pp., illus. U. S. \$29.95.

***Revised checklist of New York State plants.** 1997. By R. S. Mitchell and G. C. Tucker. New York State Museum, Albany. vii + 400 pp., U. S. \$16.50.

Environment

A classification of North American biotic communities. 1998. By D. E. Brown, F. Reichenbacher, and S. E. Franson. University of Utah Press, Salt Lake City. 152 pp., illus. U.S. \$19.95.

†**Companion to the Sand County almanac.** 1998. Edited by J. B. Callicot. University Wisconsin Press, Madison. x + 310 pp., Cloth U.S. \$27.95; paper U.S. \$14.95.

Ecologists and environmental politics: a history of contemporary ecology. 1997. By S. Bocking. Yale University Press, New Haven. xiv + 271 pp., illus. U.S. \$35.

†**Global warming.** 1997. By J. Houghton. 2nd edition. xiii + 231 pp., illus. Cloth U.S. \$59.95; paper U.S. \$22.95.

Grasslands of northeastern North America: ecology and conservation of native and agricultural landscapes. 1997. Edited by P. D. Vickers and P. W. Dunwiddle. Massachusetts Audubon Society, Lincoln. 297 pp., illus. U.S. \$27.

***Landscapes of the interior: re-exploration of nature and the human spirit.** 1996. By D. Gayton. New Society Publishers, Gabriola Island, British Columbia. 176 pp., illus. \$17.95.

†**Wetlands of the American Midwest: a historical geography of changing attitudes.** 1997. By H. Prince. University of Chicago Press, Chicago. xiii + 395 pp., illus. U.S. \$21.

White goats, white lies: the abuse of science in Olympic National Park. 1998. By R. L. Lyman. University of Utah Press, Salt Lake City. 352 pp., illus. U.S. \$29.95.

Miscellaneous

***A field guide to the life and times of Roger Conant.** 1997. By R. Conant. Canyonlands Publishing, Sandy, Utah. xix + 498 pp., illus.

†**Minutes of meetings, 1940-1942, the McIlwraith Ornithological Club, London, Ontario, Canada.** 1998. By W. W. Judd. Phelps Publishing, London, 78 pp. \$10.

Books for Young Naturalists

Arctic tundra. 1997. By M. H. Forman. Children's Press, Danbury Connecticut. 32 pp., illus. U.S. \$17.50.

Bats: shadows in the night. 1997. By D. Ackerman. Crown, New York. 32 pp., illus. U.S. \$18.

Beetle; Frog; and Snake. 1997. By R. Steffoff. Benchmark Books, Tarrytown, New York. each 32pp., illus. U.S. \$21.36.

Coral reef. 1997. By G. W. David. Children's Press, Danbury, Connecticut. 32 pp., illus. U.S. \$17.30.

Curious creatures: bats; Curious creatures: owls; Curious creatures: snakes; Curious creatures: spiders; and Curious creatures: wolves. 1997. By J. R. Taris and L. J. Taris. 16 pp., illus. U.S. \$22.95 for set + teacher's guide.

Desert discoveries. 1997. By G. Wadsworth. Charlesbridge, Waterdown, Massachusetts. 32 pp., illus. Cloth U.S. \$15.95; paper U.S. \$6.95.

Dinosaur ghosts: the mystery of Coelophysis. 1997. By J. L. Gilette. Dial, New York. 32 pp., illus. U. S. \$15.99.

Green fun: plants as play. 1997. By M. H. Gjersvik. Firefly Books, Buffalo. 42 pp., illus. Cloth U.S. \$19.95; paper U.S. \$7.95.

Housing our feathered friends. 1997. By D. T. Spaulding. Lerner, Minneapolis. 56 pp., illus. U.S. \$19.95.

Hungry animals: my first look at a food chain. 1997. By P. Hickman. Kids Can Press, Buffalo. 16 pp., illus. U.S. \$6.95.

Incredible plants. 1997. By Time-Life Books, Alexandria, Virginia. 64 pp., illus. U.S. \$17.95.

Insect wars. 1997. By S. Van Dyck. Watts, Danbury, Connecticut. 64 pp., illus. U.S. \$15.75.

Janice VanCleave's play and find out about nature: easy experiments for young children. 1997. By J. VanCleave. Wiley, New York. 122 pp., illus. U.S. \$12.95.

The octopus: phantom of the sea. 1997. By M. M. Cerullo. Cobblehill Books, New York. 57 pp., illus. U.S. \$16.99.

Protecting our feathered friends. 1997. By D. T. Spaulding. Lerner, Minneapolis. 56 pp., illus. U.S. \$19.95.

Saguaro cactus. 1997. By P. and S. Berquist. Children's Press, Danbury, Connecticut. 32 pp., illus. U.S. \$17.30.

The snake book: a breathtaking close-up look at splendid, scaly, slithery snakes. 1997. By M. Ling and M. Atkinson. DK Publishing, New York. 32 pp., illus. U.S. \$12.95.

Wild dogs: wolves, coyotes, and foxes. 1997. D. Hodge. Kids Can Press, Buffalo. 32 pp., illus. U.S. \$10.95.

*assigned for review

†available for review

Advice to Contributors

Contributors please note: due to increasing costs authors will be asked to pay \$80 for each page in excess of five journal pages beginning with volume 112, number 3. In addition \$15 will be charged for each illustration (any size up to full page) and up to \$80 per page for tables (depending on size). If grants or institutional funds are available we ask that \$80 be paid for all published pages.

Full instructions on content, preparation and submission of manuscripts appears in 111(4): 749.

FRANCIS R. COOK
Editor

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Cover: Halictid bees, *Augochlorella striata*, about to enter a pollination unit of Dwarf Lake Iris, *Iris lacustris*, Dorcas Bay, Bruce Peninsula, Ontario, photographed 25 May 1996 by Brendon M. H. Larson. See note by Larson pages 522-524.

Observations on the Breeding and Development of the Plains Spadefoot, *Spea bombifrons*, in Southern Alberta

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Klassen, M. A. 1998. Observations on the breeding and development of the Plains Spadefoot, *Spea bombifrons*, in southern Alberta. Canadian Field-Naturalist 112(3): 387–392.

The Plains Spadefoot is a possible species at risk on the Canadian prairies, yet little is known of its life history, population, and status in this area. Over a five-year period, field observations were made near Writing-On-Stone Provincial Park in southern Alberta. Correlated with highly variable local weather conditions, the time and place of calling and breeding was irregular. The rates of tadpole development reflected the ephemeral nature of the breeding ponds. These observations add to our knowledge of the life history of the Plains Spadefoot in Canada, and emphasize the variability in breeding and development of this rarely observed anuran.

Key Words: Plains Spadefoot, *Spea bombifrons*, breeding, development, Alberta.

The Plains Spadefoot, *Spea bombifrons* (often placed in *Scaphiopus*, but see Tanner 1989; Wiens and Titus 1991; and references therein*), has been identified by some authors as a species at risk on the Canadian prairies (Secoy 1987; Anonymous 1991; Seburn 1992). The grasslands and parklands of southern Alberta, southern Saskatchewan, and southwestern Manitoba represent the northern limit of its range (Figure 1), and original field observations of *S. bombifrons* are very limited for this region (see Moore 1952; Nero 1959; Cook 1960, 1965; Lewin 1963; Cook and Hatch 1964; Preston and Hatch 1986; Lauzon and Balagus 1998). Little is known of the life history, population, and status of the Plains Spadefoot on the Canadian prairies, and the breeding and larval development of this species is poorly documented in Canada (Larry Powell, University of Calgary, personal communication 1995). The effect of habitat loss on this species, and whether its populations are stable or declining, is uncertain. A recent workshop on declining amphibian populations in Canada recommended that *S. bombifrons*, among other amphibians, be the subject of an intensive monitoring program to provide life cycle data on this species (Brooks 1992).

Several populations of the Plains Spadefoot have been identified in the vicinity of Writing-On-Stone Provincial Park (49°05'N: 111°37'W) in southern Alberta (Klassen 1990), and the locality has been recognized as an appropriate site for the long-term study of this species (Brooks 1992). Over a five-year period, the breeding and larval development of the Plains Spadefoot was observed at four ephemeral ponds at this locality. Although unsystematic, these observations add to our knowledge of the life history of the Plains Spadefoot in Canada, and serve to emphasize the variability in breeding behaviour and development of this rarely observed and secretive anuran.

Methods

From 1989 to 1993, the Writing-On-Stone area was monitored for spadefoot breeding activity by the author. Plains Spadefoot mating choruses and tadpoles were noted at 15 locations in and around Writing-On-Stone Provincial Park (Figure 2). All breeding locations were ephemeral bodies of water, and included sloughs, marshy depressions, flooded cultivated fields and pastures, ditches, small pools, and river backwaters. The dates and times of calling were systematically recorded at four of these ponds (Ponds A through D) over a five-year period. Irregular and unsystematic observations of tadpole development and transformation also were made at these ponds in 1990 and 1991. Estimates of breeding population size, tadpole density, and tadpole/metamorph sizes were made. Air temperatures for the dates of mating choruses were obtained from the

*Editor's note: However, a recent account argues for continued use of *Scaphiopus* as the genus for all North American Spadefoots. Hall, J. A. 1998. *Scaphiopus intermontanus*. Catalogue of American Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles 650.1–650.17.



FIGURE 1. Approximate range of *Spea bombifrons* in Canada. (after Cook 1984).

nearest weather station, but water temperatures were not recorded.

Ponds A, B and D are located in native prairie grassland, currently used as cattle pasture and dominated by Blue Grama (*Bouteloua gracilis*), June Grass (*Koeleria macrantha*), Spear Grass (*Stipa comata*), and Northern Wheatgrass (*Agropyron dasystachyum*). Ponds A and B are well-defined sloughs with little vegetative growth and clay bottoms. These were frequently fouled by cattle throughout the observation periods, and the water was cloudy with silt and cow manure. Pond C was a fairly deep, clay-bottomed pool, located in an irrigated field which had been under cultivation since at least 1980. It was fed by irrigation water from a pivot sprinkler system, and the water was generally clear. Although calling was heard in other irrigated and cultivated fields, Pond C was the only pond in a cultivated field where spadefoots were observed to successfully reproduce. Lastly, Pond D is a shallow pool found in a marshy, vegetated grassland depression, and remained moist even without standing water. Cattle did not use this pasture in the summer months, and the water was clear.

Observations on Breeding

Calling and breeding spadefoots were noted in four of the five years, but calling did not take place in all ponds in all years. Breeding choruses were noted in two ponds in 1989, four in 1990, three in 1991, and four in 1993 (Figure 2). Calling began as early as 25 May and as late as 30 June (Table 1). In 1990, spadefoots in all four ponds began calling simultaneously on the same night, while in other years they began calling from different ponds as many as 7 to 12 days apart (Table 1). In 1993, calling was heard from the same pond on two separate nights 12 days apart. In all cases, breeding followed

heavy rains which filled the ponds for the first time that season. On the day calling began, temperature minima ranged from 7°C to 10.5°C, and maxima ranged from 12.5°C to 23.5°C (Table 1). In 1992, drought conditions prevented temporary ponds from filling, and spadefoot calling and breeding was not noted at any of the ponds.

The time of day that spadefoots first began calling varied. Most calling began after dark, and in every year except 1993, it occurred immediately following thunderstorm activity (Table 1). On three occasions calling began at midday or early afternoon, and heavy rain preceded daytime mating choruses. In 1991, calling began at 12:00 immediately following a mid-morning thunderstorm. In 1993, spadefoots at three ponds began calling at 14:00, following a period of heavy rain. In all cases when calling began in the afternoon, it ceased after a few hours, and resumed again at dusk; mating choruses on subsequent days always began after sunset. The number of calling spadefoots on the first night of breeding varied widely from pond to pond and from year to year. Accurate counts were not made, but the number of calling toads in ponds ranged from an estimated several dozen to several hundred individuals. In all but two cases, calling occurred over three consecutive nights (Table 1). The number of calling spadefoots declined with each passing night.

Observations on Tadpole Development

In 1990, visits were made to various ponds on six separate dates after breeding commenced (Table 2). At six days, tadpoles were observed in all four ponds

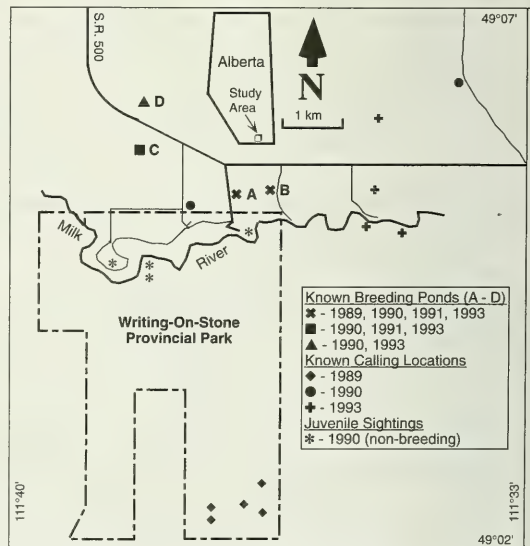


FIGURE 2. Location of Plains Spadefoot breeding ponds in the Writing-On-Stone area, southern Alberta.

TABLE 1. Observations on Spadefoot calling and breeding in Alberta 1989–1993.

Year	Pond	Calling Dates	Time	Weather Conditions (day of first calling)*: Max/Min Air Temp (°C); 24 hr Precipitation (mm)
1989	A	1-3? June	22:00	23.5°/10.5°; heavy downpour (8.0 mm); thunderstorm activity
	B	1-3? June	22:00	as above
1990	A	25-27 May	23:30	14°/7°; steady rain (10.4 mm, 55.4 mm in previous 48 h); thunderstorm
	B	25-27 May	23:30	as above
	C	25-27 May	22:30	as above
	D	25-27 May	22:00	as above
1991	B	22-24 June	ca. 22:00	18°/10.5°; heavy downpour (1.2 mm, 30.2 mm in previous 72 h); thunderstorm activity
	C	29 June-2? July	15:00	as above
	A	30 June-21 July	12:00	as above
1992		no calling/breeding noted		drought conditions; no ponds filled
1993	C	1 June, 13 June	23:00	12.5°/9.5°; steady rain (15.2 mm)
	A	13-15 June	2:00	18.5°/7.5°; steady 36 h rain (54.8 mm in previous 72 h)
	B	13-15 June	12:00	as above
	D	13-15 June	2:00	as above

*Environment Canada, Masinasin Weather Station

with bodies and tails totalling an estimated 9-10 mm in length. At 12 days, tadpoles were estimated to be 18 to 20 mm long (including the tail) in all four ponds. At this point, large numbers of tadpoles were observed in all ponds, with the most noted in Ponds C and D. At 28 days in Pond D, legs were still not apparent on any of the tadpoles observed, and the pond was nearly dry. At 48 days, large numbers of tadpoles approximately 40 mm in length (including tails) were observed feeding in Pond A, while dozens of newly transformed metamorphs approximately 25 mm in length were observed on the grassy verges of the same pond. At 60 days, Pond A was reduced in size by half and densely populated with tadpoles, most with rear legs and many with front legs and tails. No metamorphs were noted at the margins of the pond. By 72 days, all four ponds were completely dry. Juvenile spadefoots were observed on 8 July, 25 July, 5 August and 25 August at loca-

tions 1 km, 2 km, 2.25 km, and 2 km, respectively, from the nearest known breeding pond (Figure 2).

In 1991, visits were made to various ponds on thirteen separate dates after breeding commenced (Table 3). Because spadefoots in the three ponds emerged on different days, the 1991 observations are discussed separately for each pond.

Pond A: At 7 and 8 days after breeding, after a week of cool, rainy weather, no evidence of egg masses or tadpoles was noted. At 20 days, the water of Pond A was deeper than noted previously, and it held a high density of tadpoles approximately 20 mm in length (including tail) and still without legs. At 28 days, some tadpoles had reached a length of 30 mm including the tail, and most had small but fully-formed rear legs. By 34 days, some tadpoles had reached 45 mm in length, with fully formed rear legs. The first transformed metamorph spadefoot was also observed in the grass beside the pond. It

TABLE 2. Development observations 1990.

1990	Day	Pond A	Pond B	Pond C	Pond D
31 May	6	tadpoles: 9-10 mm	tadpoles: 9-10 mm	tadpoles: 9-10 mm	tadpoles: 9-10 mm
6 June	12	tadpoles: 18-20 mm; high density	tadpoles: 18-20 mm; high density	tadpoles: 18-20 mm; high density	tadpoles: 18-20 mm; high density
22 June	28	no observations	no observations	no observations	tadpoles: legless; pond nearly dry
12 July	48	tadpoles: 40 mm; high density of metamorphs: 25 mm	no observations	no observations	no observations
24 July	60	tadpoles: rear legs, many front legs; no metamorphs	no observations	no observations	no observations
5 August	72	pond dry	pond dry	pond dry	pond dry

TABLE 3. Development observations 1991.

1991	Day	Pond A	Day	Pond B	Day	Pond C
29 June	7	no activity observed			1	breeding
30 June	8	no activity observed	1	breeding		no observations
12 July	20	tadpoles: 20 mm; high density	12	no activity observed	13	tadpoles: 10-15 mm; high density
20 July	28	tadpoles: 30 mm; fully developed rear legs	20	tadpoles: high density	21	tadpoles: 30 mm; rear legs developing
26 July	34	tadpoles: 30-45 mm; all with rear legs; first metamorph, 20 mm plus vestigial tail		no observations		no observations
27 July	35	more transformed toads in grass	27	tadpoles: all with small rear legs; no metamorphs noted		no observation
28 July	36	tadpoles: range from only rear legs to all four legs; many metamorphs in grass		no observations		no observations
30 July	38	tadpoles: much lower density; many with front legs; no metamorphs in grass		no observations	31	tadpoles: some with 4 legs; low density; metamorphs: 10 mm, high density in grass
3 August	42	tadpoles: low density; very large; most with small rear legs; a few with front legs		no observations		no observations
6 August	45	same as previous date		no observations		no observations
7 August		no observations	38	pond nearly dry; some tadpoles struggling in mud; very high mortality; a few metamorphs nearby	39	tadpoles: low density; very large; most with rear legs, some with front legs
15 August	54	tadpoles: very few; pond nearly dry	45	pond dry		no observations
24 August	63	some water remaining; no activity observed			56	water present; no activity

had a vestigial tail and a body approximately 20 mm in length. More metamorphs were observed on the following two days, while tadpoles ranged in development from those with rear legs only to some with all four legs. By 38 days, the density of tadpoles had decreased, and many had developed four legs. No transformed spadefoots were observed. At 42 and 45 days, the density of tadpoles had decreased dramatically, but those remaining were very large, most had poorly formed rear legs, and only a few had front legs. By 54 days, the pond was much smaller, and few tadpoles were observed. No spadefoot activity was observed at 63 days, although some water still remained in the pond.

Pond B: At 12 days, the shallow water of Pond B showed no evidence of tadpoles. At 20 days, Pond B had shrunk considerably in size. Hundreds of tadpoles were observed feeding in the deeper water, but their size was not estimated. At 27 days, numerous tadpoles with small rear legs were observed, but

measurements were not taken. By 38 days the pond was nearly dry, with only a few muddy depressions remaining, due to a week of extremely high temperatures. In some areas, large numbers of dead tadpoles were baked into the dried mud, while a few tadpoles were found struggling in mud in moist areas. The desiccated bodies of partially transformed spadefoots were littered across the surface of the dried area. A dozen or so fully transformed live spadefoots, some with mud caked on their bodies, were observed in the grass near the pond.

Pond C: At 13 days the deep water of this irrigation-fed pond held a very high density of tadpoles, ranging from approximately 10 to 15 mm (including tails). At 21 days, tadpoles had grown to 30 mm, and many had developed rudimentary rear legs. By 31 days, the density of tadpoles was significantly reduced, and the water was only 5 cm deep. Some of the tadpoles had developed all four legs but remained in the pond. Hundreds of recently trans-

formed spadefoots were also observed among the vegetation along the margins of the pond. These metamorphs were much smaller than those observed at Pond A, and averaged about 10 mm in body length, with vestigial tails a few millimetres in length. At 39 days, the water in Pond C remained the same depth as the previous week, largely due to continued irrigation of the field. On this date, no further transformed spadefoots were noted on the margins of the pond, but a number of tadpoles with well-developed rear legs continued to be active in the water. A few of the tadpoles had four legs and a tail. No tadpoles or metamorphs were noted at 56 days, although water was still present.

Discussion

In four of the five years, conditions suitable to initiate the breeding period of *S. bombifrons* occurred anywhere from late May until early July, which corresponds to the range in breeding dates previously reported for Alberta (Lewin 1963; Nero 1959) and Manitoba (Preston and Hatch 1986). Although irregular, the dates of breeding were closely correlated to weather conditions. Breeding at Writing-On-Stone was initiated only after sufficient rainfall raised the water table and filled the breeding ponds; localized moisture conditions caused the breeding periods at different ponds to be separated by up to two weeks in the same year. In the year lacking sufficient rains to fill the ponds, choruses were not heard and breeding was not observed. This observation is consistent with the mating strategy of other spadefoot populations, which avoid breeding or may not even emerge in drought years (Russell and Bauer 1993).

Overall, mating behaviour and the conditions associated with breeding were similar to those reported for *S. bombifrons* in Montana (Black 1970) and Oklahoma (Bragg 1965). All mating choruses began immediately after a period of heavy rain in warm temperatures, with maximum daytime air temperatures ranging from 12.5°C to 23.5°C. Most calling began immediately following thunderstorm activity during the late evening, although thunderstorms also preceded daytime calling in one case. Although calling was most intense on the first night of the breeding chorus, calling continued for several consecutive nights, presumably by unmated males (Bragg 1965).

In response to the short duration of ephemeral ponds, spadefoot tadpoles metamorphose with one of the fastest rates for any amphibian (Russell and Bauer 1993:187). Overall, observed transformations began somewhat later and continued longer than the three to four weeks reported elsewhere for *S. bombifrons* under natural (Bragg 1965) and laboratory (Trowbridge 1942) conditions. In this study, the earliest observed transformations began in one case at some point between 21 and 31 days after breeding,

and in a second instance between 28 and 34 days after breeding. Tadpoles also demonstrated considerable variation in their rate of development within and between ponds. Although the earliest transformations occurred in large numbers approximately one month after breeding, coinciding with the earliest dates of pond desiccation, additional transformations were observed as much as 48 days after breeding. Tadpoles continued to develop for up to two months, but it is unknown if transformations were continuous over the entire period. Low numbers of developing tadpoles were observed as much as 60 days after breeding, and presumably some transformations occurred at least eight weeks after breeding.

The highly variable tadpole development rates may reflect the presence of both fast-developing carnivorous morphs and slow-developing omnivorous morphs within a single pond, as observed in other populations of *Spea bombifrons* (Bragg 1965; Pfenning 1992) and *Scaphiophus couchii* (Newman 1989). This adaptation capitalizes on the uncertain duration of temporary ponds: carnivorous tadpoles, which are also frequently cannibalistic, are better adapted to short duration ponds, while omnivorous tadpoles grow larger and have a greater rate of survival in long duration ponds (Newman 1989; Pfenning et al. 1993). Indeed, tadpoles older than 30 days appeared substantially larger in size than the earliest metamorphs, suggesting that they would be larger at transformation. Changing population density and food levels have also been shown to result in variable rates of development in other spadefoot species, including *Scaphiophus holbrooki* (Semlitsch and Caldwell 1982) and *S. couchii* (Newman 1994).

The observation that spadefoots successfully reproduced in ponds heavily disturbed by cattle indicates that grazing is not necessarily incompatible with the breeding activities of this species. However, the relative breeding success of spadefoot populations utilizing ponds disturbed by cattle versus those utilizing undisturbed ponds is unknown. The fact that spadefoots bred successfully in a pond located in a cultivated field also indicates that not all agricultural disturbances of temporary sloughs necessarily prevent this species from reproducing. However, where calling or breeding occurred in cultivated areas, the fields were irrigated regularly, creating artificial wetlands. Prairie sloughs which are drained and cultivated will not provide suitable breeding habitat for spadefoots. It also remains unknown if cultivation disturbs or injures buried spadefoots, particularly in the summer months when the spadefoots inhabit shallow burrows in moist soil (Black 1970; Bragg 1965). A fuller understanding of the impact of grazing, cultivation, and other agricultural practices on the success of spadefoot breeding might be critical to assessing the population, status, and future prospects of this species in Canada.

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Long-term Persistence of DDT in Shrews, Soricidae, from Maine

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Environmental contaminants (e.g., DDT: dichloro diphenyl trichloroethane) can bioaccumulate in ecosystems, causing reproductive failure and death among species at higher trophic levels. We examined levels of DDT among Soricidae from forested sites in northern Maine in control areas and in areas that were sprayed with DDT to control Spruce Budworm (*Choristoneura fumiferana*). We also examined persistence of DDT in Soricidae six times over 28 years, 1966–1994. Mean total DDT levels were significantly higher ($P < 0.05$) in Soricidae from sprayed areas than control areas in most years, yet levels have declined significantly ($P < 0.05$) over time. Mean DDT levels in insectivorous small mammals had not reached pretreatment levels, even 30 years after spraying had ceased. Prevalence of DDT metabolites confirmed that contamination in this location is from previous and not current sources.

Key Words: Shrews, Soricidae, Masked Shrew, *Sorex cinereus*, DDT, forest soils, Maine.

Extensive aerial spraying of DDT (dichloro diphenyl trichloroethane) to control Spruce Budworm (*Choristoneura fumiferana*) was conducted in northern Maine and the Maritime Provinces from the late 1950s to mid 1960s to protect timber resources. In Maine, some areas received only one application, and no area received more than three total applications over this time period (Dimond and Sherburne 1969); no additional DDT or other organochlorines have been applied in Maine since 1967 (Irland et al. 1988). A partial ban on DDT in the United States, and a complete ban on DDT in Canada was initiated in 1972. Only limited use was permitted in the United States until 1974, after which it was banned completely.

Despite restrictions in both the United States and Canada, long term persistence of DDT has been found across North America (Miles et al. 1978; Johnson et al. 1988; Szeto and Price 1991; Dimond and Owen 1996). Miles et al. (1978) found only limited degradation of DDT over four years in Ontario soils and Pham et al. (1993) found DDT in almost all samples, at all times of the year, in sediments in the St. Lawrence River basin in Quebec. Owen et al. (1977) reported that DDT in soil residues in 1976 from northern Maine were as high as 4.5 ppm, and these levels were not statistically different from DDT levels observed in 1967. On the same study area, Dimond and Owen (1996) found that only one of four sites showed a significant decline in DDT soil levels by 1983. Further, in 1993, approximately half of the DDT still remained in the soil from applications in the 1950s and 1960s (Dimond and Owen

1996), and several studies have shown that bioaccumulation of DDT continues to occur in eastern North America (Wienmeyer et al. 1987; Welch 1994).

Extensive work has been done on contaminant levels of resident fauna in northern Maine up to 10 years post spray (Dimond et al. 1968a; Dimond et al. 1968b; Dimond and Sherburne 1969; Dimond et al. 1974; Dimond et al. 1975; Knupp et al. 1976). At the same study site as ours, Dimond and Sherburne (1969) reported that insectivorous small mammals (hereafter insectivores) had total DDT levels up to 41 ppm, 10–40 times higher than the residues in herbivorous small mammals (hereafter herbivores). Residues within insectivores showed little reduction nine years after application; yet levels from herbivores appeared to be approaching pretreatment conditions during the same period (Dimond and Sherburne 1969). Despite abundant literature on DDT as an environmental contaminant, we found information on residual levels in North American small mammals for a period longer than 10 years post spray to be rare (Blus et al. 1987).

Shrews (Short-Tailed, *Blarina brevicauda*; Pygmy, *Microsorex hoyi*; Masked, *Sorex cinereus*; and Smoky, *S. fumeus*) are excellent candidates for contaminant studies because they have extremely high metabolic rates, high rates of food consumption, and are common and easily captured (Morrison et al. 1959; Vogel 1980). Dimond and Sherburne (1969) suggested that body levels of 40 ppm DDT was an acute lethal level for shrews; populations of shrews have crashed following DDT application in both orchards (Rudd et al. 1981) and forested habi-

tats (Herman and Bulger 1979). Further, shrews are short lived which makes them good indicators of current levels of DDT in the surrounding ecosystem. As predators, shrews should demonstrate bioaccumulation of DDT if it is present in the environment.

We studied long-term persistence of DDT in Soricidae six times over a 28-year period beginning two years after spraying had ceased. We examined differences in bioaccumulation of DDT between sprayed and control areas for insectivores in 1966, 1967 and 1971. Due to insufficient sample size only one species, the Masked Shrew (*Sorex cinereus*), was analysed separately. We also investigated persistence of DDT in insectivores and examined fluctuations of the three main metabolites of DDT (DDT, DDE, DDD) in insectivores over time.

Methods

We conducted our study at two sites near Portage Lake, Aroostook County, Maine. These sites were part of an industrial forest with a sparse human population, dissected by unimproved roads, and interspersed with seasonal dwellings and small settlements. The landscape east of our study area was dominated by agriculture, where DDT has been applied at various times in the past. We sampled in forested habitats 3 to 10 km west of these extensive agricultural lands to minimize potential contamination. Movements of up to 600 and 800 m have been recorded for Short-tailed Shrews and Masked Shrews respectively (Churchfield 1990; Faust et al. 1971) and movements of up to 4 km have been recorded for the Common Shrew (*Sorex araneus*) (Teglstrom and Hanson 1986). Therefore we cannot rule out that some contamination may have occurred through shrew movement and dispersal. However, we think it is unlikely that enough shrews moved into the study site from these agricultural areas to significantly affect this study.

Our first site was approximately 100 ha in size and was located in Township 14 Range 5 WELS (46°53'N, 68°24'W) near Beaver Brook, and was dominated by northern hardwoods (*Betula papyrifera*, *Acer saccharum*, *Fagus grandifolia*). A second site approximately 100 ha in size was located in Township 13 Range 7 WELS (46°47'N, 68°37'W) near Sterling Brook occupied by a spruce-fir (*Picea* spp., *Abies balsamea*) forest. Across northern Maine, DDT was applied by aircraft at 0.89 kg/ha encompassing 100 000-1 000 000 ha per treatment (Dimond and Sherburne 1969). The Sterling Brook site was sprayed in 1960, 1963, and 1964, and the Beaver Brook site was sprayed in 1958, 1960, and 1964. We chose control sites that each were approximately 70 ha in size and were located near La Pomkeag Stream in Township 8 Range 5 WELS (46°20'N, 68°22'W), near Route 11 in Township 8 Range 8 WELS (46°21'N, 68°47'W), and near

Beech Mountain in Township 10 Range 8 WELS (46°32'N, 68°46'W). These three areas remained unsprayed and encompassed a variety of forest types similar in composition to sprayed sites.

Forest soils at these sites had a well-developed spodic horizon. Deep soils were classified as coarse-loamy, mixed, frigid, Aquic or Oxyaquic Haplorthods, or where shallow to bedrock as Lithic Haplorthods (Soil Survey Staff 1992). The soils in this area have low microbial populations, low pH, slow decomposition and consequently high levels of organic matter (Owen et al. 1977), which together may aid in persistence of DDT residues (Edwards 1966).

We combined unreported data from 1971-1973 and 1994 with those of 1966-1967 which were previously documented (Dimond and Sherburne 1969). Field work was carried out in June-August 1966, 1967, 1971, 1972, 1973, and August 1994. We collected small mammals using snap traps baited with peanut butter and rolled oats and pitfall traps constructed of number 10 canning tins buried to the ground surface and partially filled with water. Snap traps were omitted in 1994 as only shrews were desired and pitfalls are more effective for capturing shrews (Blackburn and Andrews 1992). We placed 10 trap stations at 10 m intervals along 100 m transects. Transects were 161 m apart. A trap station consisted of one pitfall and three snap traps. Two transects were placed in each of the two sprayed areas, while three transects were placed in each of the three control areas to include the variety of habitats surrounding the sprayed area (Dimond and Sherburne 1969). We altered the sampling protocol slightly in 1994, by placing 10-13 pitfall traps at 10 m intervals along three 100-130 m transects in both of the sprayed areas. Samples were collected twice daily for one week in 1994. During 1966-1973, we collected small mammals at two to three day intervals for eight weeks, and badly decomposed specimens were discarded. All specimens were identified using Brown and Russell (1976) and Burt and Grossenheider (1980). Upon capture, specimens were weighed, and stored frozen in plastic bags until chemical analysis. We assumed all shrews from control areas were at or near pretreatment levels of DDT by 1972. Consequently, we did not analyze these animals for DDT residues after that time.

In all years prior to 1994, some specimens were analyzed individually. Conversely, some specimens in 1966, 1967, and 1971, and all specimens in 1994 were analyzed as pooled homogenates. Each homogenate contained 2-8 individuals of a single species representing either adults, immatures, or specimens of unknown age; each homogenate from 1994 contained five adult Masked Shrews only. We prepared single specimens and pooled homogenates for laboratory analysis using identical procedures.

TABLE 1. Total DDT¹ levels ($\mu\text{g/Kg}$) for shrews on sprayed and control areas in Aroostook County, Maine.

Year Foraging Strategy or Species	Spray		Control		P
	(n)	Mean	(n)	Mean	
1966					
All insectivores ²	(2)	7767.0	(5)	383.2	0.051 ³
Masked Shrews	(0)		(0)		
1967					
All Insectivores	(12)	4182.5	(32)	289.7	< 0.001
Masked Shrews	(4)	4342.0	(13)	288.6	0.003
1971					
All Insectivores	(19)	3383.4	(11)	173.5	< 0.001
Masked Shrews	(9)	2767.8	(3)	110.0	0.013

¹Total DDT = DDT + DDE + DDD

²Includes Masked, Short-tailed, Pygmy and Smoky shrews.

³Probabilities < 0.017 for all insectivores (shrews) and < 0.025 for Masked Shrews alone indicate that spray and control areas were different within that year based on a Mann-Whitney U-test with a Bonferroni correction where $\alpha = 0.05$ with three comparisons for insectivores, and two comparisons for Masked Shrews.

We first rinsed specimens with distilled water and then added 100 ml of methylene chloride (ultra reanalyzed). We mixed the shrews and solvent in a Waring blender on high speeds for 10 minutes, and at low speeds for 5 minutes. We then poured the blended material into a clean jar. We placed another 100 ml of solvent in the blender as a rinse, blended on high speed for 1 minute and then added this to the blended material. We repeated this procedure with 50 ml of solvent on low speed for 1 minute as a second rinse. Before preparing each sample, we washed sample jars and blender with soap and water, and then rinsed them with 95% methanol. Samples from 1966-1973 were analyzed as previously described by Dimond et al. (1968a). We analyzed samples from 1994 by soxhlet extraction according to EPA method 8081 (U.S. Environmental Protection Agency 1992).

We classified Masked, Short-Tailed, Pygmy, and Smoky shrews as insectivores. In addition, we analyzed data from Masked Shrews separately for all years.

Because we had limited data from each sprayed site (i.e., Beaver Brook and Sterling Brook), we sought to pool these data. We used a Mann-Whitney U-test (Zar 1984) to test for differences between

total DDT levels (i.e., DDT + DDE + DDD) in the two sites for insectivores and Masked Shrews. We did not make comparisons for all years because sufficient sample sizes were not collected from each site in each year. Data from control sites were pooled prior to analysis. We examined yearly differences in total DDT levels between sprayed and control areas for insectivores and Masked Shrews again using the Mann-Whitney U-test. To protect against Type I error resulting from multiple comparisons, we set $\alpha = 0.05$ and adjusted our rejection level using a Bonferroni correction factor based on the number of comparisons for each test (Beal and Khamis 1991). Next, we used the Kruskal-Wallis test (Zar 1984) to determine if there was an overall difference in DDT levels among years among insectivores and Masked Shrews. If there was a difference, we conducted *a posteriori* analyses using a nonparametric Tukey test for unequal sample sizes (Zar 1984).

We examined fluctuations of DDT, DDE, and DDD over time in an attempt to determine if the presence of DDT loads was from a current or past source. Lastly, we fitted a curve to the insectivore DDT levels from sprayed areas to track history of declines in residual DDT and to facilitate predictions about future levels.

Results

We found no significant differences in mean total DDT levels between sprayed sites for insectivores in 1967 ($U = 6.000$, $n_1 = 10$, $n_2 = 2$, $P = 0.390$) or 1971 ($U = 47.000$, $n_1 = 10$, $n_2 = 9$, $P = 0.870$), or for Masked Shrews in 1971 ($U = 15.000$, $n_1 = 3$, $n_2 = 6$, $P = 0.121$) or in 1994 ($U = 4.000$, $n_1 = 2$, $n_2 = 2$, $P = 0.121$). Therefore, we pooled data for the two sprayed sites by year, for all subsequent analyses.

Mean total DDT levels within insectivores were higher from sprayed areas than control areas in 1967 ($U = 384.000$, $n_1 = 12$, $n_2 = 32$, $P < 0.001$, corrected

TABLE 2. Total DDT¹ levels ($\mu\text{g/Kg}$) in shrews on sprayed areas in Aroostook County, Maine.

Year	Insectivores	
	(n)	Mean
1966	(2)	7767.0
1967	(12)	4182.5
1971	(19)	3383.4
1972	(14)	2576.1
1973	(47)	2015.1
1994	(4)	109.9

¹Total DDT = DDT + DDE + DDD

TABLE 3. Comparisons¹ of total DDT² levels (ug/kg) over time among shrews from sprayed sites in Aroostook County, Maine.

Foraging Strategy or Species	Year					
	High DDT Level ←			→ Low DDT Level		
All Insectivores	1966	1967	1971	1972	1973	1994
	7767.0	4182.5	3383.4	2576.1	2015.1	109.9
Masked Shrews	1967	1971	1973	1972	1994	
	4342.0	2767.8	1530.0	798.3	109.9	

¹Underscores indicate years within foraging type where DDT levels were not different ($P > 0.05$) based on nonparametric Tukey test for unequal samples.
²Total DDT = DDT + DDE + DDD

rejection level = 0.017) and 1971 ($U = 209.000$, $n_1 = 19$, $n_2 = 11$, $P < 0.001$, corrected rejection level = 0.017), but not in 1966 ($U = 10.000$, $n_1 = 2$, $n_2 = 5$, $P = 0.051$, corrected rejection level = 0.017) (Table 1), although the latter likely reflects small sample size. Data from Masked Shrews followed this relationship as total DDT levels on sprayed sites were again higher than on control sites in 1967 ($U = 52.000$, $n_1 = 4$, $n_2 = 13$, $P = 0.003$, corrected rejection level = 0.025) and 1971 ($U = 27.000$, $n_1 = 9$, $n_2 = 3$, $P = 0.013$, corrected rejection level = 0.025) (Table 1).

Year of collection significantly affected mean total DDT levels for insectivores ($H = 31.048$, $df = 5$,

$P < 0.001$) and Masked Shrews ($H = 20.864$, $df = 4$, $P < 0.001$) from sprayed areas. Residues in insectivores declined in every year in which samples were taken (Tables 2, 3). Mean total DDT levels in Masked Shrews from sprayed areas also generally declined between 1967 and 1994 (Table 3, Figure 1).

For insectivores, DDE increased with time, while DDT and DDD decreased (Figure 2). Although DDT levels for insectivores on control sites were 70 times lower in 1994 than in 1966, these shrews had not yet reached pretreatment levels.

Discussion

In control areas, there appears to have been some contamination despite no direct application because we found low levels of DDT. Alternate sources of

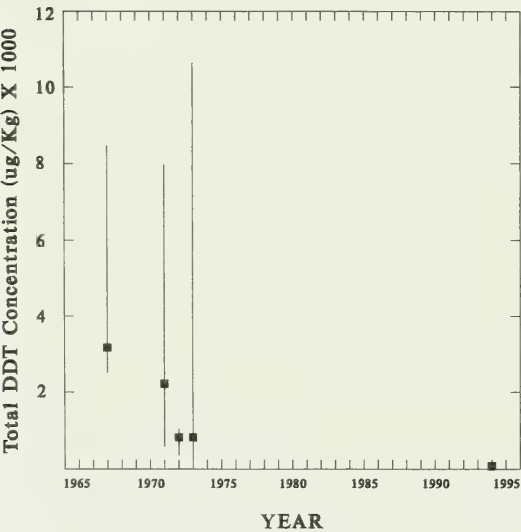


FIGURE 1. Total DDT concentrations (median and range) in Masked Shrews in sprayed areas from Aroostook County, Maine.

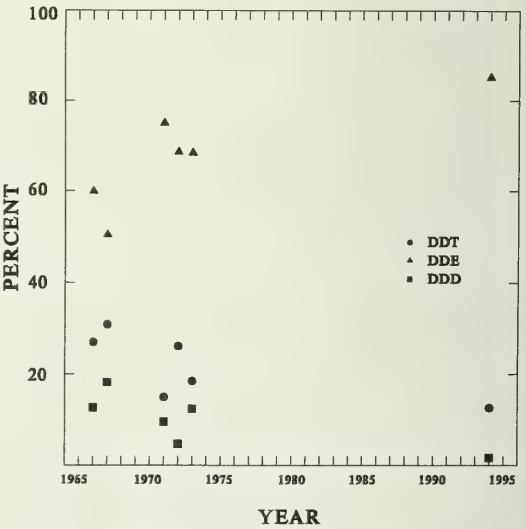


FIGURE 2. Percent of DDT metabolites for insectivores from Aroostook County, Maine.

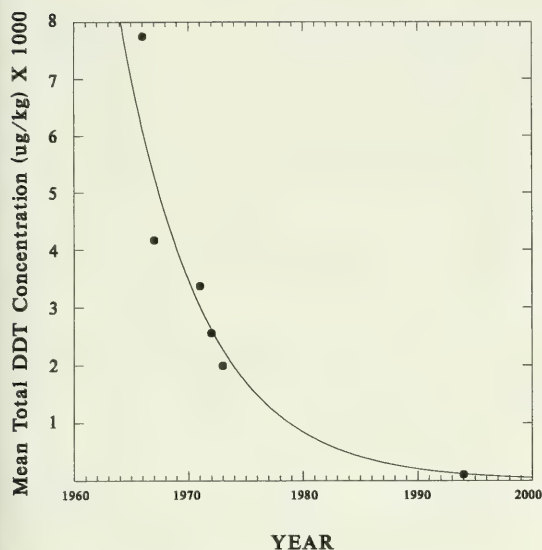


FIGURE 3. Decline of mean total DDT levels among insectivores from Aroostook County, Maine.

DDT in this area likely resulted from drift during aerial spraying or from movement of forest biota.

Shrews forage by preying on various insects (including Spruce Budworm), worms, and slugs, as well as by scavenging (Whitaker and Mumford 1972; Jennings et al. 1991). Slugs and earthworms can accumulate high levels of DDT (Forsyth et al. 1982; Beyer and Krynitsky 1989), and DDT Residues have been found in earthworms 20 years after treatment (Beyer and Krynitsky 1989). Further, bioaccumulation of DDT through shrews eating contaminated earthworms has been demonstrated (Forsyth et al. 1982). Effects of bioaccumulation are clearly shown in the comparisons of insectivores and herbivores by Dimond and Sherburne (1969).

Insectivores, including Masked Shrews, experienced a decline in DDT levels over time on both sprayed and control sites (Table 3). Levels from 1994 were approximately 20 \times lower than levels in 1973 for insectivores and separately for Masked Shrews.

Soil samples from northern Maine have shown an increase in DDE and DDD, with a decrease in DDT over time (Dimond and Owen 1996). When DDT decreases, while DDE and DDD increase, it indicates the weathering of DDT (Schmitt et al. 1990; Wade et al. 1994). The metabolism of DDT to DDE in animals is usually accomplished by dehydrodechlorination (Schmitt et al. 1990). Further reductive dechlorination to DDD occurs in some species, but to a lesser extent (Edwards and Millburn 1985). In our study, DDE increased while DDT and DDD decreased over time (Figure 2); DDD was the least represented metabolite in our samples.

Hebert et al. (1994) found that high DDE concentrations indicated a historic source of DDT. Furthermore, the shrews in our study area are short-lived, nonmigratory, have dispersal distances of under 5 km, and have limited home ranges, thus they are good representatives of local and current DDT levels in this ecosystem. Therefore, we concluded that the source of contamination was from a previously-applied, local source and that there has been no illegal application.

Not since application have insectivores on our study area approached the lethal levels suggested by Dimond and Sherburne (1969). Buckner and McLeod (1971*) reported that small mammal species composition, population density, age structure, sex ratios, breeding conditions, and fecundity had no relationship to a gradient of DDT in a New Brunswick study which had similar DDT applications as our study area. Shrews in our study, however, may be a risk to predators which feed on them. Because stored fat has higher concentrations of DDT, during times of stress when these reserves are used, debilitating levels may be reached by higher order consumers (Forsyth 1972; Clark and Krynitsky 1983).

Losses of DDT from an ecosystem can occur by volatilization, water runoff, chemical degradation, and removal by the harvesting of organic matter (Woodwell et al. 1971). Despite these low levels in herbivores reported by Dimond and Sherburne (1969), DDT levels in insectivores had not reached background levels by 1994, 30 years after spraying had ceased and appear to be declining at a decreasing rate. Blus et al. (1987) also reported persistence of DDT in small mammals for at least 12 years post spray in Washington orchards. We speculate that DDT levels in insectivores on our northern Maine sites may not reach background levels for another 10-15 years, which would be 40-45 years post spray (Figure 3).

Dimond and Owen (1996) reported a half time of 20-30 years for DDT residues in soils on our study sites. They also found very little movement of DDT from the organic layer to the mineral soil below suggesting continued potential for biotic uptake. Szeto and Price (1991) found that organochlorines persist much longer in soils with high rather than low organic matter, and that organic matter was the most important factor in determining the persistence of DDT. Consideration should be given to the rate of decomposition on the forest floor whenever a new pesticide is being considered for application in forest ecosystems.

While DDT has declined to trace levels in most places throughout the U.S., it is still a problem in several toxic "hotspots" in the southwest and north-

*See Documents Cited Section.

west (Clark and Krynsky 1983; Henny et al. 1984; Fleming and Cain 1985; White and Krynsky 1986; Johnson et al. 1988). Welch (1994) reported DDE concentrations that exceeded 10 ppm in addled Bald Eagle (*Haliaeetus leucocephalus*) eggs, and up to 2.2 ppm in blood levels of nestlings in Maine. Given these DDE levels reported by Welch (1994), in soils by Dimond and Owen (1996), and the results of this study, perhaps northern Maine should be added to a list of problem sites.

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Activity and Use of Active Gravel Pads and Tundra by Caribou, *Rangifer tarandus granti*, Within the Prudhoe Bay Oil Field, Alaska

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We used ground observations and time-lapse videography to determine timing, activity, duration of use, and response to disturbance of Caribou (*Rangifer tarandus granti*) in relation to parasitic insect activity on 18 gravel pads and tundra within 1000 m of roads and pads in the Prudhoe Bay oil field, Alaska between 27 June and 31 July 1993. We found no differences in distribution of bull dominated, cow/calf dominated, or mixed sex Caribou groups on gravel pads or tundra; but there were differences in Caribou group activities on gravel pads and tundra. Caribou groups ran more often on tundra than on gravel pads. Caribou ran less often when mosquito (*Aedes* spp.) levels were low and more often when mosquito levels were moderate to high. Average group sizes were larger at high mosquito levels. Caribou were recorded on nine active gravel pads 2534 (42.9%) of 5906 hours that activity was monitored with time-lapse videography. Walking was the predominant activity while on gravel pads followed by standing and running. Caribou were observed standing under elevated production facilities and pipelines, and in shade next to buildings enclosing well heads, presumably to avoid harassment by parasitic insects. Caribou were recorded on gravel pads between 1300 and 2000 hours (ADST) with peak numbers occurring between 1300 to 1400 and 1800 to 1900 hours (ADST). For most vehicle and human disturbances, Caribou on gravel pads responded by changing location on the pad.

Key Words: Caribou, *Rangifer tarandus granti*, Prudhoe Bay, Alaska, oil field, post-calving, road survey, time-lapse video, activity, insect harassment.

A number of studies have reported that Caribou (*Rangifer tarandus granti*) occur close to oil field facilities during the insect season (White et al. 1975; Curatolo et al. 1982*; Curatolo and Murphy 1986; Dau 1986; Murphy and Curatolo 1987; Pollard et al. 1996a,b; Cronin et al. 1998). In fact, gravel pads and roads provide insect-relief habitat similar to sparsely vegetated gravel bars and Caribou are often observed standing, running, or lying on or next to gravel pads, roads, pipelines, and buildings (Pollard et al. 1996a). Oil field facilities and roads are built on a gravel base up to 1.6 m thick which insulates the underlying permafrost, preventing thawing and subsidence. Among facilities within the Prudhoe Bay oil field (PBOF), Alaska, are 53 producing well pads, 31 non-producing well pads, eight gathering centers, two gravel landing strips for jet aircraft, and two base camps (Pollard et al. 1996b). Total area covered by gravel within the PBOF is approximately 21 km² (Walker et al. 1987). All facilities are connected by an approximately 220 km-long network of primary and secondary gravel roads (Pollard et al. 1996a).

Structures on active production sites include well houses enclosing active well heads, pipelines, reserve pits, and large elevated production facilities (modules). During 1993, we used ground observations and time-lapse videography to characterize and quantify Caribou use of gravel pads and tundra within 1000 m of roads in the Prudhoe Bay oil field, Alaska.

Methods

Road Surveys of Active Gravel Pads, Roads, and Tundra

We conducted daily road surveys to record Caribou activity and use of 18 active gravel pads, roads and adjacent tundra areas in the Western Operating Area of the PBOF. These pads included those designated as A, B, C, D, E, F, G, H, K, M, N, P, R, S, U, W, X, and Y (Figure 1). Road surveys began on 27 June and continued through 31 July 1993. Surveys were conducted between 0900 and 1800 hrs Alaska Daylight Savings Time (ADST). One or two observers in separate vehicles conducted the surveys along two designated routes (Figure 1). Between one and three circuits of each route were completed daily, depending on the number of observers available and the relative abundance of Caribou in the study area. Because some

*See Documents Cited section

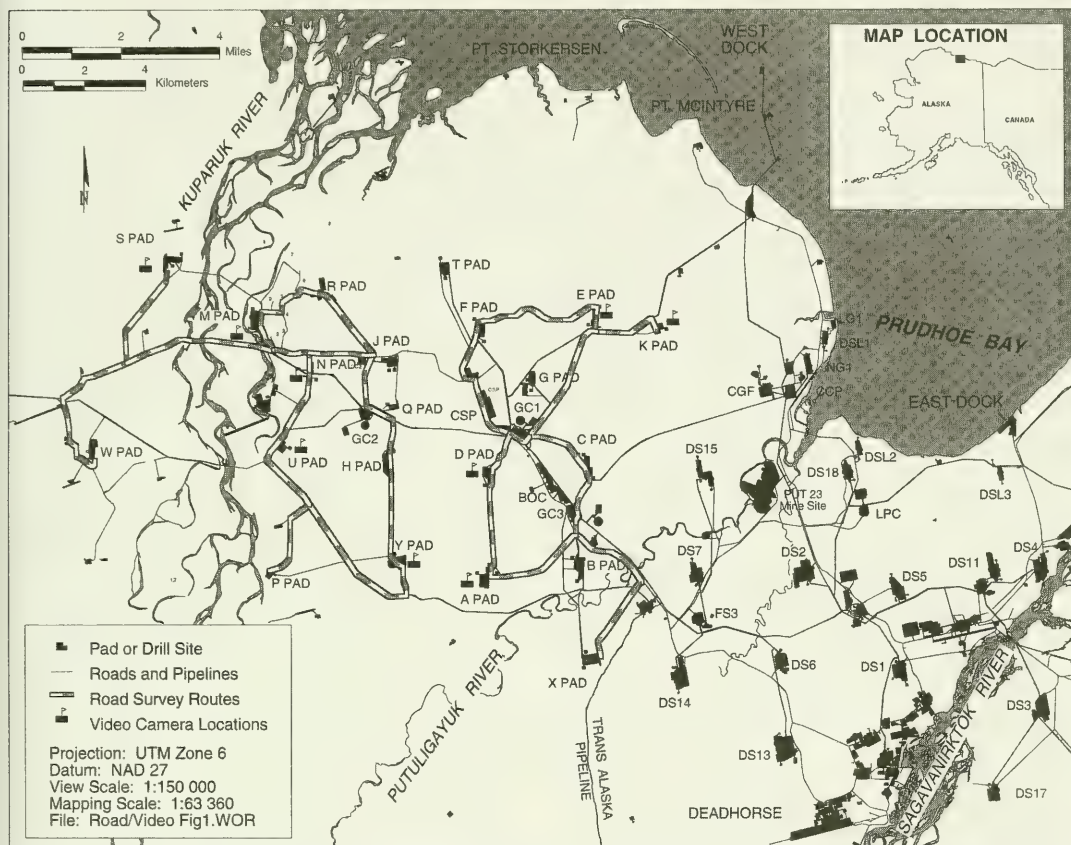


FIGURE 1. Location of road survey routes and time-lapse video cameras used to monitor Caribou activity in the Prudhoe Bay oil field, Alaska, summer 1993.

Caribou groups were counted more than once per day, total daily counts do not represent an accurate count of the number of Caribou in the area on a given day; aerial surveys provided that information (Pollard et al. 1996a). Caribou groups on pads, roads, and tundra areas within 1000 m of pads and roads were observed, and locations were marked on 1:31 680 scale maps. Data included: date, time, group size, group type, and the activity of Caribou during the observation. Group types were classified as (1) bull-dominated, (2) cow/calf-dominated [based on $\geq 50\%$ representation by the sex/age class], (3) mixed groups [based on $< 50\%$ representation by any of the sex/age classes], or (4) unclassified sex/age composition. Activity categories were classified as standing, lying, walking, running, and feeding. Overt reactions to insect harassment were also recorded when observed as erratic running, head-down stance, shaking of body and head, and sneezing (Espmark 1968). The level of insect harassment was classified for mosquitoes as none, mild, moderate, or high; and for oestrid flies

as present, or unknown. Assessment of insect abundance was based on sweep net counts for mosquitoes and sticky trap results for oestrids (Pollard et al. 1996a).

Chi-square and Spearman Rank Correlation tests were used to compare associations, and Kruskal-Wallis one-way ANOVA was used to test differences among means (Zar 1984). $P \leq 0.05$ was considered significant.

Time-lapse Videography of Caribou on Active Pads

Caribou use of gravel pads was continuously monitored using time-lapse video cameras on nine of the active gravel pads used in the road surveys, including pads designated A, D, E, K, M, N, S, U, and Y (Figure 1). Camera location varied on each pad, but most cameras were placed such that several well houses and the adjacent gravel pad areas were visible. Some cameras were focused on the elevated production modules to monitor Caribou aggregations underneath structures.

Each video-recording assembly consisted of a GYYR™ TLC1800-DC time-lapse video cassette

TABLE 1. Behavioral activities of Caribou groups observed within 1000 m of roads during surveys conducted 27 June to 31 July 1993, Prudhoe Bay oil field, Alaska. Multiple observations of individual Caribou are included in the data. Insect avoidance behavior was recorded in addition to the primary group activity for 7% of observations and as the primary activity for 3% of observations.

	Insect Avoidance Behavior Number of Groups (%)					Activity Number of Groups (%)					
	Head Down	Erratic Running	Shaking	Sneezing	Subtotal	Feeding	Lying	Running	Standing	Walking	Total
Group Size											
1-10	8 (18.2)	6 (13.6)	29 (65.9)	1 (2.3)	44	349 (50.1)	140 (20.1)	37 (5.3)	73 (10.5)	97 (13.9)	696
11-50	4 (23.5)	1 (5.9)	11 (64.7)	1 (5.9)	17	62 (40.5)	27 (17.6)	25 (16.3)	13 (8.5)	26 (17.0)	153
51-100	3 (23.1)	0 (0.0)	10 (76.9)	0 (0.0)	13	11 (27.5)	1 (2.5)	7 (17.5)	7 (17.5)	14 (35.0)	40
101-500	7 (33.3)	0 (0.0)	12 (57.1)	2 (9.5)	21	16 (32.0)	3 (6.0)	4 (8.0)	9 (18.0)	18 (36.0)	50
>500	1 (33.3)	0 (0.0)	2 (66.7)	0 (0.0)	3	5 (71.4)	0 (0.0)	0 (0.0)	0 (0.0)	2 (28.6)	7
Total	23 (23.5)	7 (7.1)	64 (65.3)	4 (4.1)	98	443 (46.8)	171 (18.1)	73 (7.7)	102 (10.8)	157 (16.6)	946
Group Type											
Bull	4 (7.8)	4 (7.8)	40 (78.4)	3 (5.9)	51	238 (48.7)	95 (19.4)	45 (9.2)	56 (11.5)	55 (11.2)	489
Cow/Calf	15 (41.7)	2 (5.6)	18 (50.0)	1 (2.8)	36	153 (42.9)	63 (17.6)	14 (3.9)	39 (10.9)	88 (24.6)	357
Mixed	3 (42.9)	1 (14.3)	3 (42.9)	0 (0.0)	7	21 (43.8)	5 (10.4)	7 (14.6)	6 (12.5)	9 (18.8)	48
Unclassified	0 (0.0)	0 (0.0)	2 (100)	0 (0.0)	2	31 (60.8)	8 (15.7)	6 (11.8)	1 (2.0)	5 (9.8)	51
Total	22 (22.9)	7 (7.3)	63 (65.6)	4 (4.2)	96	443 (46.9)	171 (18.1)	72 (7.6)	102 (10.8)	157 (16.6)	945

TABLE 2. Chi-square test for heterogeneity of Caribou group types observed on tundra within 1000 m of roads and on gravel pads during road surveys in the Prudhoe Bay oil field, Alaska, summer 1993.

Case		Number of Groups and Type		
		Bull	Cow/calf	Mixed
Gravel	Observed	108	84	14
	Expected	111.6	83.4	11
	Cell Chi-square	0.11	0	0.79
Tundra	Observed	367	271	33
	Expected	363.4	271.6	36
	Cell Chi-square	0.04	0	0.24
Overall Chi-square = 1.19		$P = 0.551$		

recorder with a Panasonic™ WV-CL 322 color CCTV digital camera equipped with a Computar™ APC auto-iris 8.5 mm semi-wide-angle lens (f 1.3). Each video system was powered by four Powersonic™ 12-volt, 80-amp batteries connected in a parallel sequence. Batteries were charged by four Solarex™ SX-56 photovoltaic panels connected in a parallel sequence. The solar panel array was oriented at a 15° angle from the gravel pad surface and faced due south. The recorder, camera, and batteries were contained in individual weatherproof aluminum housings, specially constructed and insulated to protect the equipment from extremes in environmental conditions (Figure 2).

Video cameras had a 72° field of view, and Caribou could be distinguished to a distance of about 60 m. Each camera sampled Caribou abun-

dance and activity within a 2268 m² area. However, buildings, pipelines, and other structures reduced this visible area at some pads.

The camera systems were in continual operation (24 h/day) from 3 July to 31 July and were programmed to record images at 2-sec intervals. Memorex™ Pro Cam 120-min VHS tapes were analyzed by replaying them on the GYYR™ time-lapse recorder connected to a 21-inch color television. The following data were recorded: date, time, duration, group size, group type, and activity (walking, running, standing, resting, insect harassment, and disturbances). An observation began when an individual Caribou first appeared on the screen and ended when it left the field of view or when additional Caribou appeared. A new observation was recorded as additional Caribou entered or left the field of view, or if there was a major change in activity.

Disturbances were classified as: person on foot, moving vehicle (vehicle traveled across pad without stopping), or stopped/started vehicle. Vehicles that stopped/started were usually associated with a person on foot. Caribou reactions to disturbances were classified as: not visible, no reaction, shift (movement with no change in location), move (movement with a change in location), leave, or scatter (movement in several directions). When Caribou were present but not clearly visible, reactions were classified as "not visible." All reaction types were based on gross movements, because fine movements such as heads turning or ears flicking were not discernible. Reaction was classified as "no reaction" only when Caribou were clearly visible and no movement occurred.

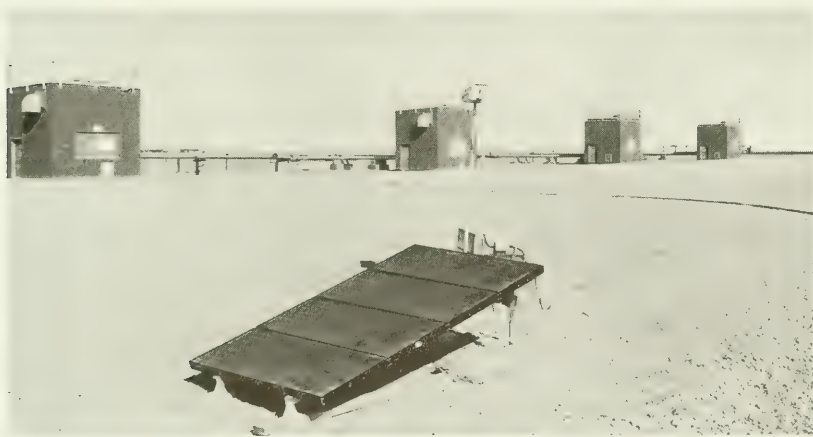


FIGURE 2. Time-lapse video assembly consisting of a video recorder, digital color camera (mounted on post), and an array of photovoltaic panels connected to 12-volt batteries which was used to monitor Caribou activity during summer 1993, Prudhoe Bay oil field, Alaska. Buildings in the background are well houses.

TABLE 3. Chi-square test for heterogeneity of activities in which Caribou groups were engaged on tundra within 1000 m of roads and on gravel pads during road surveys in the Prudhoe Bay oil field, Alaska, summer 1993.

Case		Activity				
		Lying	Running	Standing	Walking	Insect Avoidance
Gravel	Observed	52	6	87	44	56
	Expected	72.7	27.8	43.2	66.5	34.8
	Cell Chi-square	5.9	17.06	44.46	7.63	12.9
Tundra	Observed	113	57	11	107	23
	Expected	92.3	35.2	54.8	84.5	44.2
	Cell Chi-square	4.65	13.44	35.02	6.01	10.16
Overall Chi-square = 157.23		$P < 0.001$				

Results

Road Surveys

Effect of Group Size and Type on Activity and Habitat Use

Feeding was the predominant activity for groups of 1-10 Caribou (50%), 11-50 Caribou (41%), and >500 Caribou (71%, Table 1). Walking was the predominant activity for groups of 51-100 Caribou (35%), and 101-500 Caribou (36%, Table 1). When summarized by group type for all groups, feeding predominated (43-61%, Table 1).

Most observations (73% of 974) were of Caribou groups composed of ≤ 10 individuals. Mean group sizes were calculated for each day to allow comparison to daily weather and insect conditions. Daily mean group size ranged from 1 to 373 Caribou. Daily mean group sizes were greatest on 4 July, 10

July, 18 and 19 July and 27 July. Generally most Caribou groups were located on the tundra 30 of 35 days. Exceptions, when more Caribou groups were located on gravel pads, occurred on 11 July 60%, on 12 July 50%, on 14 July 100%, on 15 July 58%, and on 27 July when 53% were located on gravel pads. On all of these dates, except 27 July, few Caribou were observed within the oil field and mean group sizes were small ranging from 1 to 3. On 18 and 19 July, large numbers of Caribou were moving through the oil field, and 42 and 31% of groups, respectively, were on gravel pads.

Group composition on gravel pads and tundra within 1000 m of roads was used to test for differences in habitat selection by group types. Groups observed on either tundra or gravel, but not both, were used in the analysis. There was no significant

TABLE 4. Chi-square test for heterogeneity for Caribou group activity, within 1000 m of roads, by the level of mosquito activity during road surveys in the Prudhoe Bay oil field, Alaska, summer 1993.

Mosquito Activity ¹	Caribou Groups	Activity				
		Feeding	Lying	Running	Standing	Walking
None	Observed	180	64	4	45	48
	Expected	160.0	61.8	26.0	36.9	56.4
	Cell Chi-square	2.49	0.08	18.62	1.80	1.24
Mild	Observed	152	70	16	49	80
	Expected	172.2	66.5	28.0	39.7	60.7
	Cell Chi-square	2.83	0.19	5.14	2.20	6.17
Moderate	Observed	93	28	447	3	19
	Expected	89.2	34.4	14.5	20.5	31.4
	Cell Chi-square	0.17	1.20	72.93	14.97	4.90
High	Observed	18	9	5	5	9
	Expected	21.6	8.3	3.5	5.0	7.6
	Cell Chi-square	0.60	0.05	0.63	0.00	0.26
Overall Chi-square = 136.01		$P < 0.001$				

¹Based on sweep net counts of mosquitoes (see Pollard et al. 1996a).

TABLE 5. Characterization of selected time-lapse video observations for Caribou groups spending >1 hour on gravel pads in the Prudhoe Bay oil field, Alaska, during 1993.

Date	Start	End	Elapsed	Number of Caribou	Group Types	Description
K Pad						
18 July	15:17:00	17:19:30	2:02:30	20-80	cow/calf, unclassified	Large groups enter and stand beneath module.
27 July	11:07:01	12:30:10	1:23:09	3	cow/calf	Stand under module. Stay 83 minutes underneath module.
27 July	13:59:06	18:27:08	4:28:02	1-5	cow/calf, unclassified	Groups come and go during this period, 99 minutes with no Caribou present. Stand under module, move back and forth from module to pipeline. Unclassified group of 3-5 remain standing underneath the module for 126 minutes.
M Pad						
10 July	12:15:33	16:05:00	3:49:27	1-200	mixed	Large group of 200 move in and stay about 23 minutes, stand and rest around well houses, some in shade. Most move out with a few smaller groups remaining. About 100 return at 13:00 to stay for 45 minutes. These move out and smaller groups pass by staying from 1 to 15 minutes.
N Pad						
16 July	12:21:54	15:17:36	2:55:42	2-200	cow/calf, mixed, unclassified	Begins with 5 Caribou moving in and standing under module. Groups come and go. Cow/calf group of 200 stays 10 minutes, unclassified group of 50 remains 60 minutes.
27 July	13:11:14	18:45:25	5:34:11	1-3	unclassified	Primarily standing under module. Group leaves, then returns and stands under the module. One unclassified animal stands 76 minutes, unclassified groups of 2-3 stand 96 minutes with 1 to 2 coming and going, while remaining Caribou stand under the module.
S Pad						
18 July	12:40:10	19:03:04	6:22:54	1-30	unclassified	Caribou stand under the module and pipeline. Group of 15 stand for 91 minutes with no change in number or activity. Other smaller groups spend periods of 8 to 42 minutes standing under the module.
27 July	16:37:18	17:59:17	1:21:59	5	unclassified	Group stands under module.
U Pad						
18 July	16:27:56	18:29:12	2:01:16	20-200	mixed, cow/calf	Stand near the well houses and in reserve pit. Mixed group of 200 walk by and about 20 stay for 104 minutes, then about 130 Caribou walk by for 12 minutes.
26 July	16:50:11	18:55:18	2:05:07	40	unclassified	Stand next to well houses, many in shade.
27 July	13:19:36	18:10:08	4:50:32	5-7	unclassified	Come out of reserve pit and stand next to well houses and under module.
Y Pad						
26 July	18:05:05	19:05:18	1:00:13	18-35	cow/calf	Stand next to well houses, many in shade.

TABLE 6. Kruskal-Wallis test for the amount of time spent on gravel pads by Caribou group type. Data from time-lapse videography of Caribou on nine active gravel pads, Prudhoe Bay oil field, Alaska, summer 1993.

Group Type	Mean Rank	n	Mean Time (min) on Pads	SD	Mean Number of Caribou/Group	SD
Bull-dominated	130.1	97	2.15	6.17	7.0	17.97
Cow/calf-dominated	145.4	144	2.41	8.23	7.7	20.21
Mixed	178.5	50	5.24	15.7	31.7	49.05
Kruskal-Wallis Statistic (H) = 10.917						P = 0.004
Bull-dominated	112.8	97	2.15	6.17	7.0	17.97
Cow/calf-dominated	126.5	144	2.41	8.23	7.7	20.21
Kruskal-Wallis Statistic (H) = 2.239						P = 0.1346

difference in ($P = 0.55$, $n = 877$) for group types between gravel pads and tundra (Table 2). It appeared that different group types (bulls, cow/calf, mixed) used gravel pads and tundra similarly. However, there was a significant difference in Caribou activities ($P < 0.001$, $n = 556$) between gravel pads and tundra (Table 3). A considerably higher proportion of groups ran on tundra than on gravel pads (Table 3). Conversely, a considerably higher proportion of groups stood on gravel pads than tundra (Table 3). On gravel pads, more Caribou than expected exhibited insect avoidance behavior; and, conversely, fewer Caribou than expected used this behavior on tundra (Table 3). Fewer groups than expected were lying on gravel pads, and more groups than expected were lying on tundra (Table 3). Similar results were obtained for walking behavior (Table 3). Standing accounted for 51% of the overall Chi-square value (Table 3).

Vehicle based road survey observers believed they had little or no influence on Caribou behavior. Caribou groups generally did not alter their behavior in response to observers unless groups were encountered on or very near roads or pads. When approached at close range, Caribou responded by raising their heads, shifting position, or walking away.

Effect of Insect Abundance on Caribou Activity and Group Size

The relationship between Caribou activity and mosquito levels was significant ($P < 0.001$, $n = 1344$, Table 4). Running contributed 72% to the overall Chi-square value (Table 4). Caribou groups ran less often than expected at low mosquito levels and more often than expected at moderate to high mosquito levels (Table 4). Fewer groups than expected stood at moderate mosquito levels, while more than expected stood at mild or no mosquito levels (Table 4). More groups than expected fed at the no mosquito level, while fewer than expected fed at mild and high mosquito levels.

For all mosquito activity levels, the numbers of groups lying were similar to expected values (Table

4). Oestrid flies were also present on at least 14 days during the study and probably also influenced Caribou activity. Prior to the onset of the oestrid season from late June to mid-July when mosquitoes were prevalent, Caribou were predominately on tundra. After mid-July, mosquito activity decreased and remained low through the end of July. Oestrid flies were present on most days from mid- to late-July. During this period, Caribou use of gravel pads was more pronounced than during the first part of July, when mosquitoes alone were present.

For all group sizes and group types, the most commonly observed insect avoidance behavior was shaking, followed by head down posture (Table 1). Erratic running primarily occurred in small groups, and sneezing was rarely observed. Caribou group size and mosquito activity were significantly correlated ($r_s = 0.07$, $P = 0.043$, $n = 974$). Daily mean group size was greatest (139) at the highest level of mosquito activity.

Time-lapse Video Data

A total of 5906 hours of time-lapse videography was collected between 4 and 31 July. Approximately 10% of the total video record (594 hours) was unusable for analysis because of poor visibility. Periods of poor visibility resulted from low light levels during the early morning hours. A total of 739 Caribou observations (group size range 1-200 animals) were recorded using gravel pads. Multiple observations of animals were included in the records as Caribou moved in and out of the camera's field of view. Approximately 61% of all groups observed could not be classified with certainty. Of the groups that were classified, 33% were bull-dominated, 50% were cow/calf-dominated, and 17% were mixed.

Duration of Use and Activity of Caribou on Gravel Pads

Caribou were videographed on gravel pads for a total of 3022 minutes. Between 4 and 9 July, few Caribou used gravel pads. Mosquito activity was moderate to high during this time period and few Caribou were in the study area (Pollard et al.

1996a,b). On 10 July, there was an increase in the number of Caribou using gravel pads and in the amount of time Caribou remained on pads. Seventy-six observations were recorded of Caribou walking (55%), and standing (33%) on pads for a total of 312 minutes on 10 July. Mosquito activity was high on this date; and the majority of observations were large groups of Caribou that split, coalesced, and moved back and forth across M Pad (Table 5). Road and aerial surveys (Pollard et al. 1996a,b) documented approximately 2300 Caribou in the vicinity of M Pad between 1000 and 1600 hours (ADST) on 10 July.

During 11 to 15 July, only 48 Caribou in nine observations were videographed on gravel pads. Road surveys during this period indicated few Caribou were in the oil field. Between 16 and 19 July, Caribou were videographed for a total of 1166 minutes (39% of total) on gravel pads. Road and aerial surveys documented large numbers of Caribou moving through the study area during this time period, particularly on 18 and 19 July (Table 2; Pollard et al. 1996a,b). On 18 July, Caribou were observed on gravel pads for 653 minutes, with most observations occurring on K, S, and U Pads (Table 5). Of 316 observations on gravel pads (16 to 19 July), 61% were walking, 22% standing, and 16% running. As on previous dates, few groups were resting; however, there were many instances of individuals lying on gravel, usually in the shade of well houses or underneath production modules. Mosquito activity during 16 to 19 July was negligible, but oestrids were present on all days.

Caribou were videographed on gravel pads for a total of 165 minutes between 20 and 25 July, which was less than the total time Caribou were observed on pads during the previous four days. Road surveys indicated that relatively few Caribou were using the study area (20 to 25 July), and those present were located primarily on tundra. Mosquito activity was mild to nonexistent and oestrids were present on 4 of 6 days during 20 to 25 July.

On 26 to 27 July, the number of Caribou groups and the amount of time Caribou were videographed on pads increased from levels observed the previous week. On 27 July, Caribou were videographed for 1057 minutes, or 35% of the total video record for the study. Most of these observations consisted of small, unclassified groups (1-7 individuals) on K, N, S, and U Pads. Walking was the primary activity for Caribou groups on this date (43%), followed by standing (31%), and running (25%). Caribou were standing under production modules and pipelines, and in the shade next to well houses (Table 5). This type of behavior was presumably to avoid harassment by oestrid flies (Espmark 1968), which were active on all days these behaviors were recorded.

There were significant ($P = 0.004$, $n = 291$) differences among group types and time spent on pads (Table 6). Mixed groups were observed on gravel pads for a considerably longer period of time than either bull or cow/calf groups. However, mixed groups were, on average, about four times larger than bull or cow/calf groups, and it may be that dura-

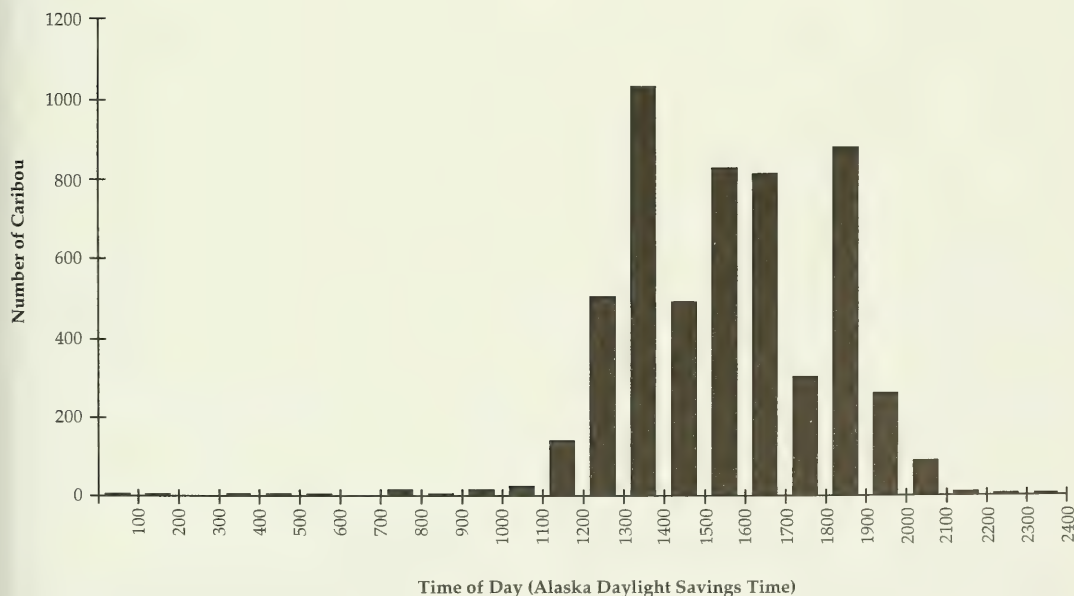


FIGURE 3. Diel periodicity of Caribou as recorded by time-lapse video on gravel pads in the Prudhoe Bay oil field, Alaska, summer 1993.

tion of use of gravel pads by Caribou reflected group size not group type. We found no significant difference ($P = 0.135$, $n = 241$) between bull and cow/calf groups for the amount of time spent on gravel pads (Table 6), supporting the hypothesis that group size may be more important than group type in determining the length of time caribou use gravel pads.

Diel Patterns of Use of Gravel Pads by Caribou

The majority of Caribou groups were observed on gravel pads between 1300 and 2000 hours (ADST), with a peak between 1700 and 1800 hours (ADST). However, these figures include observations of groups consisting of a single Caribou. When graphed as the total number of Caribou observed, the peak was at 1300 to 1400 and 1800 to 1900 hours (ADST, Figure 3).

Effects of Disturbance on Caribou Using Gravel Pads

Moving vehicles accounted for 88% of disturbances ($n = 200$), followed by vehicles that stopped/started (11%), and people on foot (2%). Reactions were not discernible for 53 of 200 disturbances (27%). Of those reactions that were discernible ($n = 147$), the most common reaction was movement with a change of location on the pad (39%), followed by no reaction (22%), shifting (21%), leaving (16%), and scattering (2%).

The most common reaction to a moving vehicle was movement to a new location on the pad (42%). On several occasions, Caribou were observed walking or running in front of a vehicle for a short distance before moving out of the vehicle's path. In other instances, they moved immediately out of the vehicle's path to a new location on the pad. Other Caribou showed no reaction to moving vehicles (25%) or shifted (24%). No reaction generally occurred when Caribou were not close to the path of the vehicle. Shifting occurred when Caribou were close to or in line with the path of the vehicle. Caribou generally reacted by moving a short distance and returning to their original locations within a few seconds. Scattering occurred in response to moving vehicles and was the result of a vehicle driving through a group of Caribou. The group responded by splitting with individuals and/or smaller groups heading in opposite directions away from the vehicle's path. Responses to moving vehicles were probably influenced by a group or an individual's proximity to and the speed of the vehicle.

The most common reaction to vehicles that stopped/started was movement with a change in location (50%). For example, on 27 July at K Pad, Caribou standing beneath a module moved to the far end of the module but, within a short time, returned to the center in response to vehicles arriving and departing. Generally, upon arrival, a person would exit the vehicle, walk a short distance to the module

stairs, climb the stairs, and enter the module. This group's response, movement away from the disturbance and return to their original position, occurred several times. Although there were only three occurrences of a person on foot, in all three cases Caribou responded by leaving the pad (100%).

Discussion

Road survey data indicated that when mosquitoes were the dominant insect pest, Caribou were observed more often on tundra than on gravel pads. When oestrid flies were predominant, road survey and time-lapse video data indicated overall use of gravel pads by Caribou increased. Level of mosquito abundance influenced Caribou activity and group size. Caribou ran more at high mosquito levels than at low levels. Other researchers have reported similar findings (Fancy 1983; Murphy and Curatolo 1987; Johnson and Lawhead 1989*). Caribou group size was positively correlated with mosquito abundance. Though average group size begins to increase soon after the peak of calving, mosquito harassment apparently is a major factor causing large aggregations (Roby 1978; Johnson and Lawhead 1989*).

Other studies have suggested that Caribou are more likely to occur close to oil field facilities and activities during the insect season (White et al. 1975; Curatolo et al. 1982*; Curatolo and Murphy 1986; Dau 1986; Murphy and Curatolo 1987, Pollard et al. 1996a,b; Cronin et al. 1998). Harassment by oestrid flies can often override any tendency to avoid development-related structures and/or activities (White et al. 1975; Curatolo et al. 1982*; Dau 1986; Murphy and Curatolo 1987). Indeed, gravel pads and roads provide insect-relief habitat similar to sparsely vegetated gravel bars (Murphy and Curatolo 1987; Pollard et al. 1996a,b), and Caribou are often observed standing or traveling on gravel pads and roads; standing, lying, or traveling in the shade beneath elevated pipelines; and lying in the shade beneath or beside buildings (Roby 1978; Fancy 1983; Murphy and Curatolo 1987; Johnson and Lawhead 1989*; Pollard et al. 1996a,b). During this study, oestrid-harassed Caribou on active gravel pads exhibited many of these same behaviors with some groups remaining on pads for periods of 1 to 4 hours. Even when disturbed by moving vehicles, Caribou most commonly just moved to another location on the pad rather than leaving the pad. Roby (1978) also noted that Caribou exhibited a higher tolerance to traffic when oestrid harassment was severe. Our results corroborate other's observations that during the insect season, Caribou often occur on and around oil field facilities to avoid parasitic insect harassment.

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Notes on Forest Succession in Old Fields in Southeastern Ontario: the Woody Species

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Changes in vegetation in plots in two abandoned hayfields were monitored during 1975–1996. Dates of arrival and cover of trees, shrubs and vines are reported here. The first tree colonists were Apple (*Malus pumila* Miller) and American Elm (*Ulmus americana* L.); the latter remains dominant. Soil properties and spatial vegetation patterns are heterogeneous. Density of seedlings and/or young clonal shoots was significantly related to the distance to a forest edge or to possible seed parents in some species.

Key Words: succession, old fields, trees, shrubs, vines, southeastern Ontario.

Forest succession in old fields is of scientific and economic interest in regions such as southeastern Ontario, where much farmland has been abandoned. Because few observational records of such succession have been made in this area (Kershaw 1993; Geomatics 1995) we present here notes on changes in two fields observed during 1975–1996. Only woody plants are reported here; a full data set, including soil measurements, is maintained by the authors, with a copy at the Ministry of Natural Resources, at Brockville.

Study Area

Two fields belonging to Queen's University Biology Station were selected, at Lake Opinicon, in Storrington Township, Frontenac County (44° 03' N, 76° 09' W). The area is close to the edge of the Canadian Shield, and has a complex geological mosaic of marble, granite and schist, overlain by sands, clays and tills (Gilbert 1994). Rocky ridges outcrop between areas with soil, and beaver marshes occupy some depressions. Maximum elevational differences between experimental plots within a field was 3 m. The Opinicon area is in Site Regions 6E and 7E of the Great Lakes-St. Lawrence Forest (Riley and Mohr 1994; Mackey et al. 1996).

Forest clearance began about 1815 and peaked by the 1880s (Rollason 1982; Riley and Mohr 1994). Each field now has forest on three sides, interrupted by a marsh on one side of the larger field.

The fields were primarily used for hay (Epp 1986). One was abandoned about 1970 and was dominated by goldenrods in 1975 (called S field for *Solidago*). The other was cut annually until 1975 (called P/G field for Ploughed/Grass). Half of the experimental plots in the P/G field were disturbed by fall ploughing in 1975. Aspects of the ecology of the fields have been described by McBrien (1983),

McBrien et al. (1983), Epp (1986), Henderson (1986), McBrien and Harmsen (1987) and McNamee (1997).

Methods

Permanent plots, each 100 m², were demarcated in 1975, 9 in the S field, and 18 in the P/G field. Nine of the latter were ploughed. Each year woody plants (and all other plants) within each plot were recorded in early and in late summer. Cover was also estimated twice each summer, using five randomly placed quadrats within each plot ($n = 270$ quadrats per y) (McBrien 1983; Henderson 1986). Woody species in a belt 10 m wide, at the edges of the adjoining forest areas, were listed four times during 1975–1996. Numbers of woody plants in plots, distances of plot centres to forest edges, and distance of plants to nearest possible parent plants were estimated in 1992 and 1994. Species richness was calculated per plot and per field. Soil texture, organic carbon and pH for each plot were sampled in 1990. Correlations were examined using 2-way ANOVA or Pearson correlation matrices.

Results

Soils

Soil texture is shown in Figure 1 as percentages of clay, silt and sand particles; the G and P plots were paired for soil type and elevation, with the 1–2 and 6–7 plots having the highest elevation in both series.

Soil moisture ranged from 9% to 67% in June 1990, organic carbon from 3% to 24% and pH from 5.9 to 7.6. Moisture content and pH are positively related to clay content and negatively to sand content. Fields differed significantly in clay content and pH, but both inter- and intra-plot variances were high. Depths to bedrock, soil colour, etc. are reported in McNamee (1997).

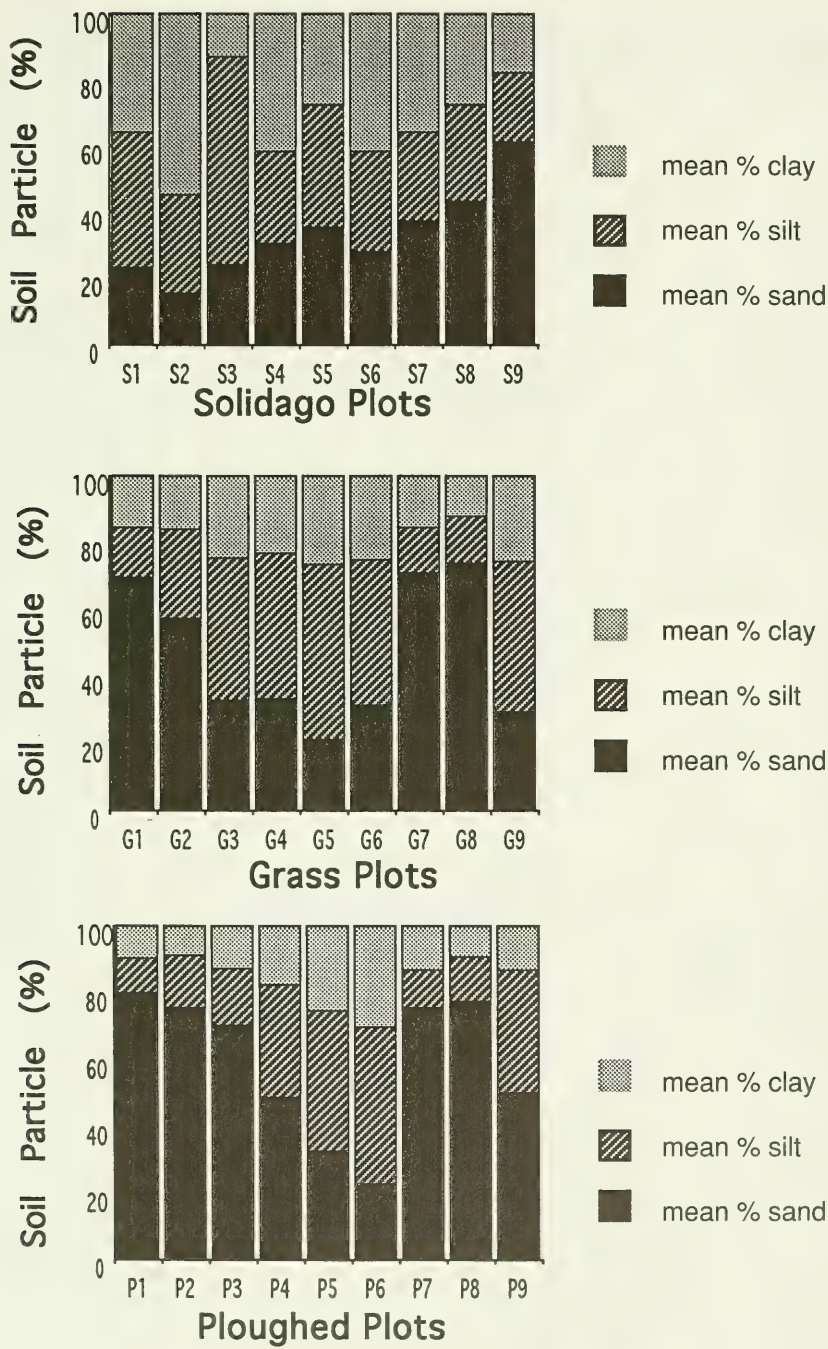


FIGURE 1. Soil textures in 27 plots; estimates are based on five samples per plot. Percentages of clay, silt and sand particles are shown.

Woody Species

Trees, shrubs and vines found in forest transects and plots are listed in Table 1, which includes Latin names, authorities and common names. Nomenclature follows Morton and Venn (1990). The earli-

est year of observation of a woody species in the field plots is shown in Table 1; S = plots in the goldenrod-dominated field, G = plots in the P/G field undisturbed after haying in 1975, and P = plots in the P/G field disturbed by ploughing in 1975.

TABLE 1. Woody species present in forest edge transects and in field plots. The year of earliest occurrence is shown separately for S, P, and G plots. Percent occurrence in all plots in all years is shown in the right-hand column.

	Common names	Present in forest transects	Date of earliest record Y1 = 1976			Percent occurrence in plots 1976-1994 (n = 513)
			P	G	S	
<i>Acer rubrum</i> L.	Red Maple	√	4	3	2	47
<i>Acer saccharum</i> Marshall spp. <i>saccharum</i>	Sugar Maple	√	4	1	1	53
<i>Acer saccharinum</i> L.	Silver Maple	√				0
<i>Alnus incana</i> spp. <i>rugosa</i> (L.) spp.						
<i>rugosa</i> (Duroi) Clausen	Rough Alder	√	19			<1
<i>Amelanchier sanguinea</i> (Pursh) DC	Juneberry	√				0
<i>Betula alleghaniensis</i> Britton	Yellow Birch	√				0
<i>Betula papyrifera</i> Marshall	Paper Birch	√	6		2	21
<i>Carya cordiformis</i> (Wagenh.) K. Koch	Bitternut Hickory	√	7	3	1	25
<i>Carya ovata</i> (Miller) K. Koch	Shagbark Hickory	√			19	1
<i>Celastrus scandens</i> L.	Climbing Bittersweet	√		13	6	6
<i>Clematis virginiana</i> L.	Virgin's Bower	—	3	1	10	45
<i>Cornus alternifolia</i> L.	Green Osier	—	19			<1
<i>Cornus amomum</i> Miller spp. <i>obliqua</i> (Raf.) J.S. Wilson	Narrowleaf Dogwood	—			19	<1
<i>Cornus foemina</i> Miller spp. <i>racemosa</i> (Lam.) J.S. Wilson	Grey Dogwood	√	3	1	5	41
<i>Cornus rugosa</i> Lam.	Roundleaf Dogwood	√	2	1	2	23
<i>Crataegus</i> spp.	Hawthorn	√	19	3	1	23
<i>Fagus grandifolia</i> Ehrh.	American Beech	√				0
<i>Fraxinus americana</i> L.	White Ash	√	9	1	1	54
<i>Fraxinus pennsylvanica</i> Marshall	Red Ash	√			19	54
<i>Juniperus communis</i> L.	Common Juniper	√		3		8
<i>Juniperus virginiana</i> L.	Red Cedar	√	6	1	19	17
<i>Malus pumila</i> Miller	Apple	√	1	1	1	48
<i>Ostrya virginiana</i> (Miller) K. Koch	Ironwood	√			2	8
<i>Parthenocissus quinquefolia</i> (L.) Planchon ex DC	Virginia Creeper	√	11	6	1	20
<i>Pinus strobus</i> L.	White Pine	√	7	4	5	20
<i>Populus balsamifera</i> L.	Balsam Poplar	√	12			17
<i>Populus deltoides</i> Bartram ex Marshall spp. <i>deltoides</i>	Eastern Cottonwood	√	3			<1
<i>Populus grandidentata</i> Michaux	Large-tooth Aspen	√	12			16
<i>Populus tremuloides</i> Michaux	Trembling Aspen	√	1	13		17
<i>Prunus pensylvanica</i> L.	Pincherry	√	19			<1
<i>Prunus serotina</i> Ehrh.	Black Cherry	√	8	10	10	24
<i>Prunus virginiana</i> L. spp. <i>virginiana</i>	Choke Cherry	√	12	2	19	30
<i>Quercus alba</i> L.	White Oak	√			8	8
<i>Quercus macrocarpa</i> Michaux	Bur Oak	√				0
<i>Quercus rubra</i> L.	Red Oak	√			8	9
<i>Rhamnus cathartica</i> L.	Common Buckthorn	√			12	3
<i>Rhus radicans</i> L. spp. <i>negundo</i> (E. Greene) McNeill	Poison Ivy	√	1	3	1	34
<i>Rhus typhina</i> L.	Staghorn Sumac	√	5		2	11
<i>Ribes cynosbati</i> L.	Gooseberry	√				0
<i>Rosa blanda</i> Aiton	Smooth Wild Rose	—		4	4	9
<i>Rubus allegheniensis</i> Porter	Blackberry	√	8	5	19	28
<i>Rubus idaeus</i> L. spp. <i>idaeus</i>	Wild Red Raspberry	√	10	1	6	33
<i>Salix bebbiana</i> Sarg.	Bebb's Willow	—		2		<1
<i>Salix petiolaris</i> Smith	Stalked Willow	√	1	1	19	18
<i>Spiraea alba</i> Duroi	Narrow-leaved Meadowsweet	√	9	3		12
<i>Thuja occidentalis</i> L.	Eastern White Cedar	—			4	3
<i>Tilia americana</i> L.	Basswood	√		6	12	5
<i>Ulmus americana</i> L.	American Elm	√	1	1	1	66
<i>Ulmus thomasi</i> Sarg.	Rock Elm	√			19	<1
<i>Vitis riparia</i> Michaux	River Grape	√		6	3	23
<i>Zanthoxylum americana</i> Miller	Prickly Ash	√		3	1	20

The right hand column of Table 1 shows the percentage of plots in which a taxon occurred, using all years ($n = 540$). This value is used as an estimate of abundance because it is applicable both to species growing as individuals and to clonal species. The most abundant trees were American Elm, White Ash, Red Ash, Sugar Maple, and Apple, and the most abundant shrub was Grey Dogwood. The most abundant vine was Virgin's Bower.

Comparison of field plots with the adjoining forest

Species found in forest transects and not in field plots were *Acer saccharinum*, *Amelanchier sanguinea*, *Betula alleghaniensis*, *Fagus grandifolia*, *Quercus macrocarpa* and *Ribes cynosbati*. The Silver Maple is in a swampy area of the forest, but apparently similar wet areas occur in the field. Species found in the field and not in the forest were *Clematis virginiana*, *Cornus alternifolia*, *C. amomum* spp. *obliqua*, *Rhamnus cathartica*, *Rosa blanda*, *Salix bebbiana* and *Thuja occidentalis*.

To give a regional perspective to the tree community, sampled in the surrounding forest belts, it can be compared to forest in the nearest area for which there is a large detailed quantitative survey, the Salmon River Valley, approximately 30 km west. The Canadian Shield portion of the Salmon Valley has similar geology, geomorphology and microclimate to the Opinicon area (Starling 1978; Crowder and Starling 1980). Twelve tree species in the Salmon Valley had importance values greater than 10; all of these, except Silver Maple (*Acer saccharinum*) were found in the Lake Opinicon field plots within ten years after abandonment.

Immigration

In ploughed plots willows, poplars, and Poison Ivy survived disturbance as shoots, and Apple and American Elm appeared as seedlings in Year 1. The mean interval between arrival of new woody species in the P plots was 6.2 years.

In the G (grass) and S (goldenrod) plots nine woody species were present in Year 1, with only American Elm and Apple as seedlings. The mean interval between arrival of new woody species was 3.8 y in G plots and 4.6 y in S plots.

Using all 27 plots, a specific mean time to arrival was estimated. For Apple and Elm the value was one year ($\bar{x} = 1$ y), followed by Poison Ivy ($\bar{x} = 1.6$ y), Sugar Maple ($\bar{x} = 2.3$ y), Red Maple ($\bar{x} = 3$ y), Grey Dogwood ($\bar{x} = 3$ y) and subsequently by Butternut Hickory, White Ash, and Virgin's Bower. Species with a mean interval of 5 y or more included White Pine, Raspberry, Virginia Creeper, and cherries. Late arrivals included both large-fruited or large-seeded plants such as oaks, and species spreading vegetatively from the forest edge, such as Balsam Poplar (see Table 1).

TABLE 2. Life forms and reproductive strategies. Column 3 is partly derived from Martin et al (1987).

	T	W	C	—	Se	—
<i>Acer</i> spp.	S	—	—	—	Se	—
<i>Alnus incana</i>	S	—	—	—	Se	—
<i>Amelanchier sanguinea</i>	S	—	—	E	Se	—
<i>Betula</i> spp.	T	W	C	—	Se	—
<i>Carya</i> spp.	T	—	C	—	Se	—
<i>Celastrus scandens</i>	V	—	C	—	—	Ve
<i>Clematis virginiana</i>	V	W	—	—	—	Ve
<i>Cornus</i> spp.	S	—	—	E	Se	Ve
<i>Crataegus</i> sp.	S/T	—	C	E	Se	—
<i>Fagus grandifolia</i>	T	—	C	—	Se	—
<i>Fraxinus</i> spp.	T	W	C	—	Se	—
<i>Juniperus communis</i>	S	—	?C	E	Se	Ve
<i>Juniperus virginiana</i>	T	—	?C	E	Se	—
<i>Malus pumila</i>	T	—	—	E	Se	Ve
<i>Ostrya virginiana</i>	T	W	C	—	Se	—
<i>Parthenocissus quinquefolia</i>	V	—	—	—	—	Ve
<i>Pinus strobus</i>	T	W	C	—	Se	—
<i>Populus</i> spp.	T	W	—	—	Se	Ve
<i>Prunus serotina</i>	T	—	—	E	Se	—
<i>Prunus</i> spp.	S	—	—	E	Se	Ve
<i>Quercus</i> spp.	T	—	C	—	Se	—
<i>Rhamnus cathartica</i>	S/T	—	—	E	Se	—
<i>Rhus radicans</i>	V	—	—	E	Se	Ve
<i>Rhus typhina</i>	S	—	C	—	Se	Ve
<i>Ribes cynosbati</i>	S	—	—	E	Se	—
<i>Rosa blanda</i>	S	—	—	E	Se	Ve
<i>Rubus</i> spp.	S	—	—	E	Se	Ve
<i>Salix</i> spp.	S	W	—	—	Se	—
<i>Spiraea alba</i>	S	—	—	—	—	—
<i>Thuja occidentalis</i>	T	W	C	—	Se	—
<i>Tilia americana</i>	T	W	C	—	Se	—
<i>Ulmus</i> spp.	T	W	C	—	Se	—
<i>Vitis riparia</i>	V	—	—	E	Se	Ve
<i>Zanthoxylum americanum</i>	S	—	—	E	Se	Ve

T = tree

S = shrub

V = vine

W = wind dispersed

C = found in caches

E = edible fruit, seed excreted

Se = seedling observed in plots

Ve = vegetative reproduction observed in plots

Colonization

Not all immigrants survived. Establishment was defined as persistence in a plot for longer than two years. The most successful tree species was American Elm, which remained in 75% of the plots in which it had germinated, followed by Apple (55%). Sugar Maple remained in 52%, White Pine 42%, Paper Birch 33% and Red Maple only 23%. The most abundant shrub, Grey Dogwood, persisted in 78% of the plots in which it had germinated.

In 1990, the density of non-clonal woody plants was estimated as individuals per m². The density for all such woody species was greatest in the S plots, followed by the P plots, followed by the G plots. The density for elm (the most abundant species) was P>S>G. Competition from forbs in the grass plots apparently persisted for two decades.

Dispersal

Table 2 lists dispersal mechanisms for woody plants found in the plots. Columns 2 and 3 are based on both observation and literature records (e.g. Martin et al. 1951). Life forms are indicated in the left-hand column.

Cover

Mean cover of woody plants increased with time throughout the period of observation, reaching 15% in the P plots, 25% in the G plots and 40% in the S plots in 1995. This trend over time was not apparent in the cover of non-woody species. Mean values obscure high variance of cover within the S and P/G fields. By 1980 some plots had become small groves of trees while others remained open field. The texture of soils also showed high variance (Figure 1), and plots with high sand content remained those with least tree cover, although cover was not significantly correlated with soil texture or moisture. To illustrate this patchiness, Figure 2 shows woody cover in selected plots over a twenty-year period. Each point is a mean for five quadrats per plot, estimated in the late summer. Figure 3 illustrates temporal trends of cover for selected species (American Elm, Apple, and White Pine) in selected plots.

Spatial patterns

After two decades, the fields are very heterogeneous; the groves of elms are in places 3 m high, and interspersed with shrub thickets and areas dominated by forbs. The densest shade is created by White Pines.

The forest edge has advanced in some places up to 3 m into the fields. Where clonal fronts are present the density of stems is positively and significantly correlated with the distance to possible parent plants; clones producing fronts include poplars, sumacs, Prickly Ash, and raspberries (cf. Matlack 1994).

Some species which did not grow as forest fronts showed significant correlations between density and distance-to-parent. For Grey Dogwood, the most abundant shrub, the values were $r = 0.512$, $p < 0.01$.

The size of field affected density and distance-to-parent relationships. In the smaller field (S) correlations for American Elms, Sugar Maple and Prickly Ash were significant, whereas in the larger field they were not.

Size of field also affected relationship of species richness of woody plants with distance-to-forest-edge. The relationship in the smaller field was significant ($r = 0.701$, $p < 0.01$). These fields can perhaps be better compared to clearings in tropical forest than to large abandoned farms (cf. West et al. 1981).

Woody plants and forbs

Some plots were dominated by goldenrods (*Solidago* spp.) at the beginning of our observations, and continued to be so for twenty years; a similar

period of goldenrod dominance has been reported in Germany (Joshi and Matthies 1996). Fluctuations in goldenrod cover in the Opinicon fields, due to herbivorous beetles and interactions with grasses, have been described by McBrien et al. (1983), McBrien and Harmsen (1987) and Henderson (1986).

Woody plants were slow to invade plots with dense goldenrod cover, which creates a thick mat of dead stems. *Solidago canadensis* has been reported to be allelopathic to some tree seedlings (Fisher et al. 1978).

Plot S5 exemplifies the effect of goldenrod cover, which was 63-65% during 1976-1988 (Figure 2). By 1995 it fell to 46%, and was made up of *Solidago canadensis* L. and *Solidago gigantea* Aiton. Until 1988 its woody cover was less than 3%, rising to 36% in 1995. Woody species involved included American Elm, Apple, Sugar Maple, Staghorn Sumac and Wild Vine. In 1995 the major woody species was American Elm, forming 16% cover, and the other woody species were Staghorn Sumac, and Blackberry, both forming part of invasive clonal fronts.

Discussion

The Lake Opinicon plots are representative of marginal areas of the Canadian Shield with a similar history of land-use; they are not representative of southeastern Ontario generally, because of its variety of rock, soil, and land-use (cf. Riley and Mohr 1994; Crowder et al. 1997). Other seres in the region include those characterized by Red Cedar, Eastern White Cedar, White Pine or Ironwood. We offer these notes to provide ecologists, foresters and landowners in the region with a time series of observations, which should be a useful addition to theoretical models (e.g., West et al. 1981; Tilman 1988). The latter are based generally on synoptic observations of fields of various ages or on analysis of the age structure of forest stands.

In the large literature on old-field succession, which followed reviews by Drury and Nesbit (1973) and Connell and Slatyer (1977), some sites comparable to those at Opinicon have been described. They include hayfields in New York State (Mellinger 1972; Mellinger and McNaughton 1975; Gill and Marks 1991), in Québec (Dansereau and Gille 1949) and in southern Ontario (Maycock and Guzikowa 1984; Reader 1990). The literature on old-field succession in Ontario has been reviewed by Kershaw (1993) and by Geomatics (1995*).

Theoretical models suggest that the first abundant pioneer trees should be wind-dispersed. The two main pioneer trees at Lake Opinicon were American

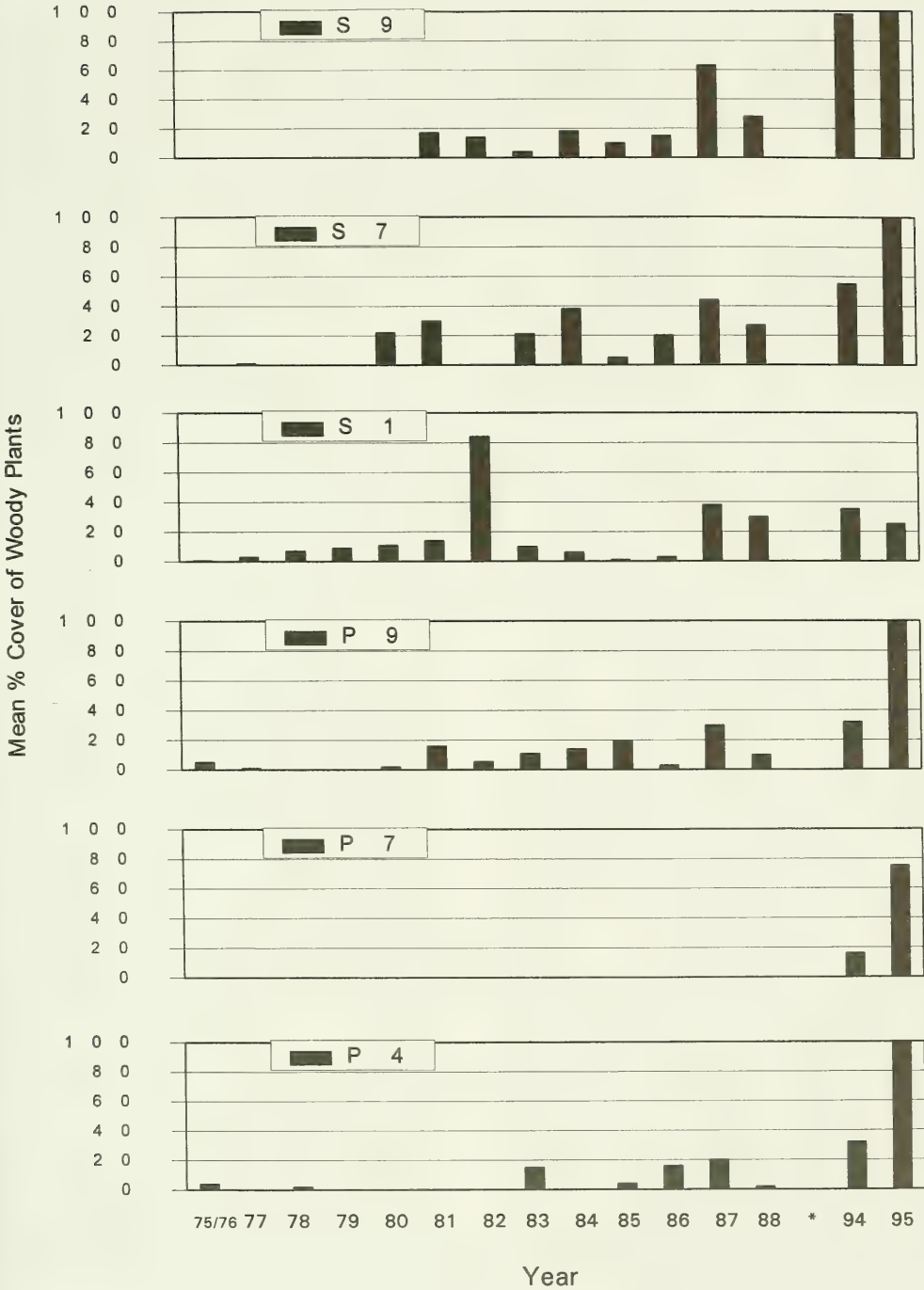


FIGURE 2. Mean percentage cover of woody plants in selected plots during 1976–1995. Note the gap in observations after 1988.

Elm, which fits the model, and Apple which does not. While maples and ashes, which are wind-dispersed with winged seeds, became abundant, pine and birch, the “orthodox” pioneer species (Geomatix 1995) did not colonize more than one quarter of the plots (cf. Table 1).

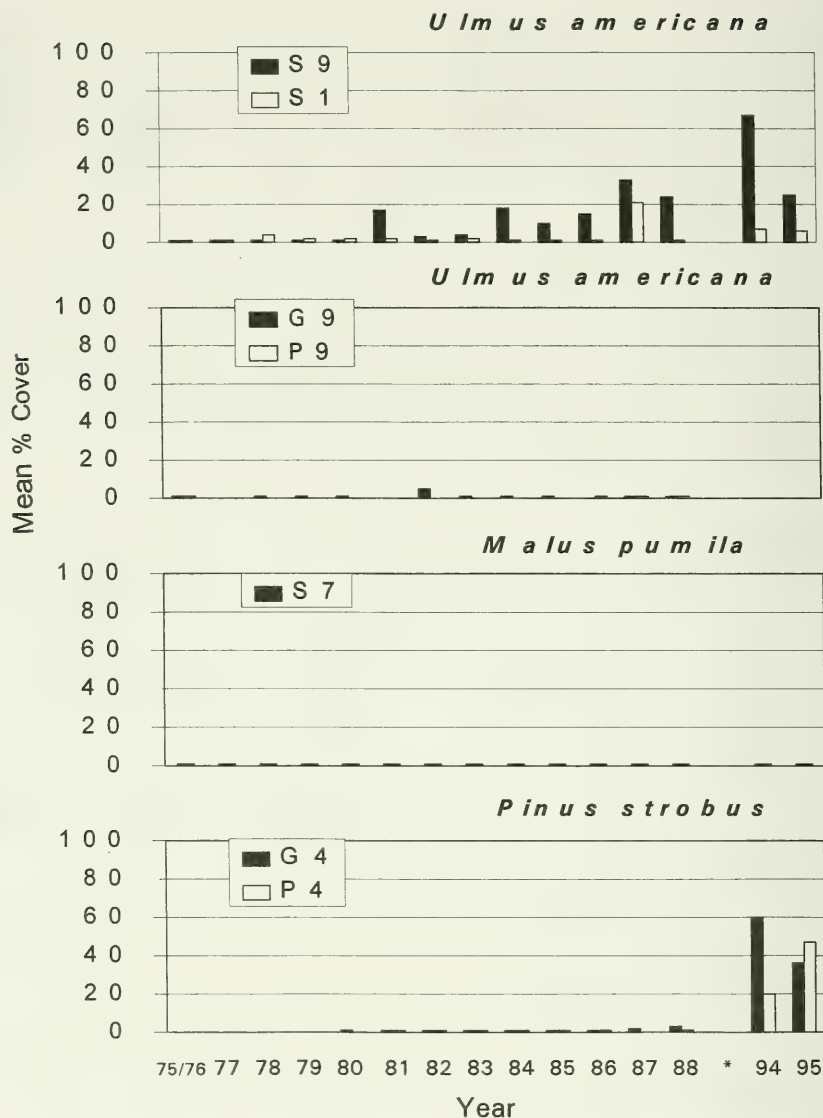


FIGURE 3. Mean percentage cover of American Elm, White Pine, and Apple in selected plots during 1976–1995.

The most abundant tree, American Elm, was reported as an old-field dominant in North Carolina (de Steven 1991a). Its success at Opinicon may have been related to unusually large seed crops produced by moribund trees in the surrounding forest; these old trees were dead from Dutch Elm Disease by 1990. The most abundant pioneer vine, Virgin's Bower, fits the wind-dispersed model; it was also able to survive haycutting and ploughing.

Apple was similar to fifteen other species colonizing the plots (including trees, shrubs and vines), in having seeds enclosed in edible fruits. Such seeds may be dispersed by Raccoons (*Procyon lotor*),

whose faeces are abundant in the plots, and by several species of passerine birds observed in the fields (McNamee 1997). The most abundant shrub with edible fruits is Grey Dogwood; it has also been reported as the most abundant shrub in abandoned fields in New York State (Mellinger 1972; Boeken and Canham 1995).

Species with edible fruits tended to co-occur; for example, two plots in the P/G field had shrub thickets each containing five such species. Presumably, once one species has become established, animals visit it to feed, and add other species when they defecate, thus acting as a focus of recruitment

(McDonnell and Stiles 1983). Using seed traps with artificial perches, McNamee (1997) found that birds preferred to perch and defecate in the open plots rather than close to the forest edge.

The heavy large nuts of hickories and oaks were presumably placed in the plots by cache-makers moving from the forest edge; they could include Blue Jays (*Cyanocitta cristata*) and Grey Squirrels (*Sciurus carolinensis*), both observed in the fields. Hickory seedlings were present from the first year of observations in the older field but did not appear in the younger field for eight years (cf. Table 1).

Some tree, shrub and vine species advanced as clonal fronts or phalanxes, into the plots (Lovett Doust 1981). They included three species of *Populus*, tall shrubs such as Prickly Ash and Staghorn Sumac, and small shrubs or vines such as Raspberry, Blackberry and Poison Ivy. A similar advance of trees into an old field has been described near Hamilton, Ontario (Lamoureux 1970).

During two decades of observations, twenty-seven woody species colonized the plots, using one or more of the various dispersal mechanisms listed above. Their different spatial patterns and their different temporal patterns, including mast years, can set up patchiness likely to persist into a future forest mosaic. The patchiness is increased by soil differences, with establishment largely depending on a species' position along a soil moisture gradient (Maycock 1963; de Steven 1991). Species cover and species density in the plots were not significantly correlated with soil properties, but the driest, sandiest plots had few or no woody plants (cf. Figures 1 and 2). Similarly in Illinois, Burton and Bazzaz (1991) found no neat correlations between tree seedling emergence and soil differences or year-to-year differences. A smaller plot size might have improved the fit between soil parameters and species cover; our plot size was chosen to include large clones of forbs.

A further cause of patchiness in the developing forest cover is competition from herbs. Growth of dense goldenrods in some plots has been described in McBrien et al. (1983), and a reciprocal relationship between goldenrod cover and woody species cover has been noted for Plot S5. Burton and Bazzaz (1991) also found that vegetation could partly predict tree seedling growth.

A developing diverse forest mosaic results from surviving seedlings and saplings; a first-year survival rate of less than 10% of seed input can be expected (Smith 1975). Observed causes of death included fungal infection, particularly in Apple, moisture deficits (McNamee 1997) and herbivory (McNamee 1997). Herbivory probably includes seed-eating by small mammals (Smith 1975). Drought and browsing were also found to be main causes of tree seedling mortality in old-fields by de Steven (1991a,

1991b). Obviously the heterogeneity and diversity of woody vegetation are increased in the Opinicone sere by the population dynamics of both seed vectors and herbivores. The main herbivores observed have been Meadow Voles (*Microtus pennsylvanicus*), White-tailed Deer (*Odocoileus virginianus*) and Beaver (*Castor canadensis*).

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Large Suprabenthic *Daphnia middendorffiana* from an Alpine Lake in the Canadian Rocky Mountains

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Exceptionally large (up to 4.0 mm) *Daphnia middendorffiana* were collected with a bottom-closing net while sampling benthos in Pipit Lake, Alberta. Such large *D. middendorffiana* have not been observed in plankton samples collected from the lake over the past 30 years, nor have such large individuals been reported in the literature. Stable nitrogen isotope ratios ($\delta^{15}\text{N}$) of the large *Daphnia* were 4.5‰ higher than smaller *Daphnia* from higher in the water column, indicating that the spatially separated *Daphnia* may use different food sources. The large *Daphnia* had *Hesperodiaptomus* resting eggs and nauplii in their guts, while the smaller *Daphnia* higher in the water column had mainly phytoplankton in their guts. Our findings highlight the need to use several different kinds of sampling gear to completely assess the fauna of a lake.

Key Words: *Daphnia middendorffiana*, Cladocera, suprabenthic, stable nitrogen isotope ratios $\delta^{15}\text{N}$, alpine lakes, Alberta, Canada.

The cladoceran, *Daphnia middendorffiana*, is a common inhabitant of high latitude lakes and ponds in the northern hemisphere. Its circumpolar distribution extends southward through the alpine regions of the Rocky Mountains and Pacific Coastal Ranges in North America and the Alps in Europe (Brooks 1957; Haney and Buchanan 1987; Patalas et al. 1994). Frequently, *D. middendorffiana* is the only herbivorous cladoceran in alpine and arctic lakes and ponds. It is one of the largest *Daphnia* species and is able to coexist with large predatory copepods in fishless habitats (Luecke and O'Brien 1983). Females up to 3.0 mm in size have been described in standard taxonomic keys (Brooks 1957; Pennak 1978).

Here we describe the occurrence of a population of unusually large (up to 4.0 mm) *D. middendorffiana* near the bottom of Pipit Lake in the alpine zone of Banff National Park, Alberta. Such large *D. middendorffiana* have not been previously observed in plankton samples from the lake, despite hundreds of vertical net tows over the past 30 years (Anderson and Donald 1978; D. W. Schindler unpublished data), nor have populations with such large-sized individuals been reported in the literature (Table 1). We suggest that the large *Daphnia* may be residents of the deep profundal zone of Pipit Lake. Their existence was previously undetected because vertical net tows do not sample near the sediment-water interface. Net tows are usually initiated 1 net length above the bottom to avoid disturbing the sediment.

We used nitrogen stable-isotope analysis and an examination of gut contents to compare the trophic

position of the large benthic *Daphnia* and the smaller pelagic morphs. Nitrogen isotope analysis has emerged as a powerful tool to define trophic position because there is a consistent increase in the ^{15}N content of consumers with increasing trophic level (Peterson and Fry 1987; Fry 1991). This is due to the preferential loss of ^{14}N by animals during nitrogen metabolism (Minagawa and Wada 1984). Because nitrogen in a consumer's tissue is derived exclusively from its diet, trophic estimates using the isotope technique are based on assimilated, not just ingested foods, and therefore complement gut analysis studies.

Study Site and Methods

Pipit Lake is a small (10.6 ha, $Z_{\text{max}} = 20.6$ m), oligotrophic, alpine (2217 m) headwater lake in the Front Ranges of the Canadian Rocky Mountains in Banff National Park, Alberta (51°36'N, 115°50'W). Morphological and chemical conditions are summarized in Anderson and Donald (1978) and Leavitt et al. (1994). The ice-free season usually lasts from early July until late September.

On 6 July 1995, just after ice out, we collected zooplankton samples from Pipit Lake with a 30 cm-diam., 64 μm -mesh plankton net hauled from a depth of 19 m (lake bottom = 20 m). Zooplankton for nitrogen isotope analysis were separated by species and placed into 500 mL Nalgene containers filled with filtered ($\leq 1 \mu\text{m}$) lake water for ≈ 4 h to allow gut clearance. Samples for identification/enumeration were preserved with 4% sugared formalin. We also sampled benthic invertebrates at the same site

with a bottom-closing net (BCN, 0.168 m² opening and 500 µm mesh; Lasenby and Sherman 1991), which samples the entire water column and the top few cm of sediment. We emptied the BCN contents into a sieve (Wilhelm and Hiebert 1996) and transferred the large *Daphnia* to a 500 mL Nalgene container to keep them alive for examination. With the aid of a Wild M5 dissecting microscope equipped with an ocular micrometer, we observed that many of these large *Daphnia* had either *Hesperodiaptomus* diapausing eggs (identified as in Parker et al. 1996) or nauplii, as well as detritus and charcoal particles in their guts. Observations were made under reflected and transmitted light with the animals in a drop of water. Fifteen individuals were allowed to clear their guts for 4 h in filtered lake water before being pooled for nitrogen isotope analysis. Gut contents of preserved *Daphnia* were examined under a compound microscope after carefully teasing apart the intestinal tracts of 10-12 individuals from the net and BCN samples in a drop of water on a microscope slide.

We identified the *Daphnia* from Pipit Lake as *D. middendorffiana* according to Brooks (1957, 1959). Although there is some uncertainty surrounding the taxonomic status of *D. middendorffiana* and its relationship to *Daphnia pulex* (Meijering 1975; Bushnell and Byron 1979; Haney and Buchanan 1987), an alternative to current taxonomic keys has not been recommended (Dodson 1981). Our identification was confirmed by A. Salki and K. Patalas of the Department of Fisheries and Oceans, Freshwater Institute, Winnipeg, Manitoba.

Methods for stable nitrogen isotope analysis closely followed those of Kling et al. (1992). The *Daphnia* were dried at 60°C, ground to a fine powder and placed in small tin capsules which were then sealed. Stable isotope ratios were measured with a Continuous Flow Isotope Ratio Mass Spectrometer

(CF-IRMS VG Optima-EG). Isotope ratios were expressed in the δ notation according to $\delta^{15}\text{N} \text{‰} = [(R_{\text{sample}}/R_{\text{standard}}) - 1] \times 10^3$, where $R = {}^{15}\text{N}/{}^{14}\text{N}$, and R_{standard} is atmospheric nitrogen. Precision of the mass spectrometer was 0.3‰.

Particulate organic matter (POM) for nitrogen isotope analysis was obtained by filtering 2 L of lake water from 2, 5, 8, 15 and 19 m through an 80 µm mesh onto a Whatman QM-A quartz fiber filter (effective wet pore size: ≈ 1.0 µm). A surface sediment sample for nitrogen isotope analysis was collected from 20 m by allowing the plankton net to settle into the sediment.

Additional net tow and BCN samples were collected in 1996 and 1997 to determine if the large *Daphnia* persisted through the open-water season or disappeared shortly after ice-out as observed for some other *Daphnia* populations. Vertical net tows and BCN hauls were taken on 7 July in 1996 and on 10, 28 July, and 14, 26 August in 1997. However, BCN hauls were not completed on 28 July 1997 because of mechanical malfunctions. In 1996, we took five replicate net tows and two BCN hauls, while in 1997, we took six replicate net tows and three BCN hauls on each sampling date. Neither gut or stable nitrogen isotope analyses were performed on these samples.

All *Daphnia* from the 1996 samples were counted and measured, while in 1997 net tow samples were sub-sampled by topping each sample up to 250 mL with distilled water and withdrawing 5 mL aliquots with a large bore automatic pipette after vigorously shaking the sample. Aliquots were taken from each sample until 50 *Daphnia* or the entire sample had been counted. All *Daphnia* from the BCN hauls were counted and measured. *Daphnia* body lengths were grouped into 0.25 mm size classes and frequencies were standardized to numbers per cubic meter.

TABLE 1. Size ranges of *Daphnia middendorffiana*/*D. pulex* reported in literature. Species names are given as identified by authors; M — *middendorffiana*, P — *pulex*, and M/P — *middendorffiana/pulex* intermediates.

Species	^a Size range mm (largest)	Location	Source
M	3.2 - 4.0 (4.0)	Pipit Lake, Alberta	This study
M	2.5 - 3.0	—	Brooks (1959)
M	up to 3.0	—	Pennak (1978)
M	2.5 - 3.0 (3.5)	—	Brooks (1957)
M ^b	2.4 - 3.2 (3.4)	Imikpuk Lake, Point Barrow, Alaska	Edmondson (1955)
M	2.32 - 2.92	Pond C, Point Barrow, Alaska	Dodson (1975)
M	2.2 - 3.2 (3.5)	Pond C, Point Barrow, Alaska	Stross et al. (1980)
M	2.2 - 2.6 (3.2)	Point Barrow, Alaska	Chisholm et al. (1975)
P, M/P	2.12 (3.7)	Pond 1, Tuktoyaktuk, Northwest Territories	Meijering (1975)
P, M/P	0.58 - 2.25 ^c	Pond 18C, Cumberland Peninsula, Baffin Island, Northwest Territories	Bushnell and Byron (1979)

^aWe assume reported sizes are measured from base of spine to top of head (cf. Dodson 1981).

^bOriginally identified as *D. pulex* var. *tenebrosa*, later reclassified as *D. middendorffiana* by Brooks (1957).

^cImmatures in collections (see Bushnell and Byron 1979).

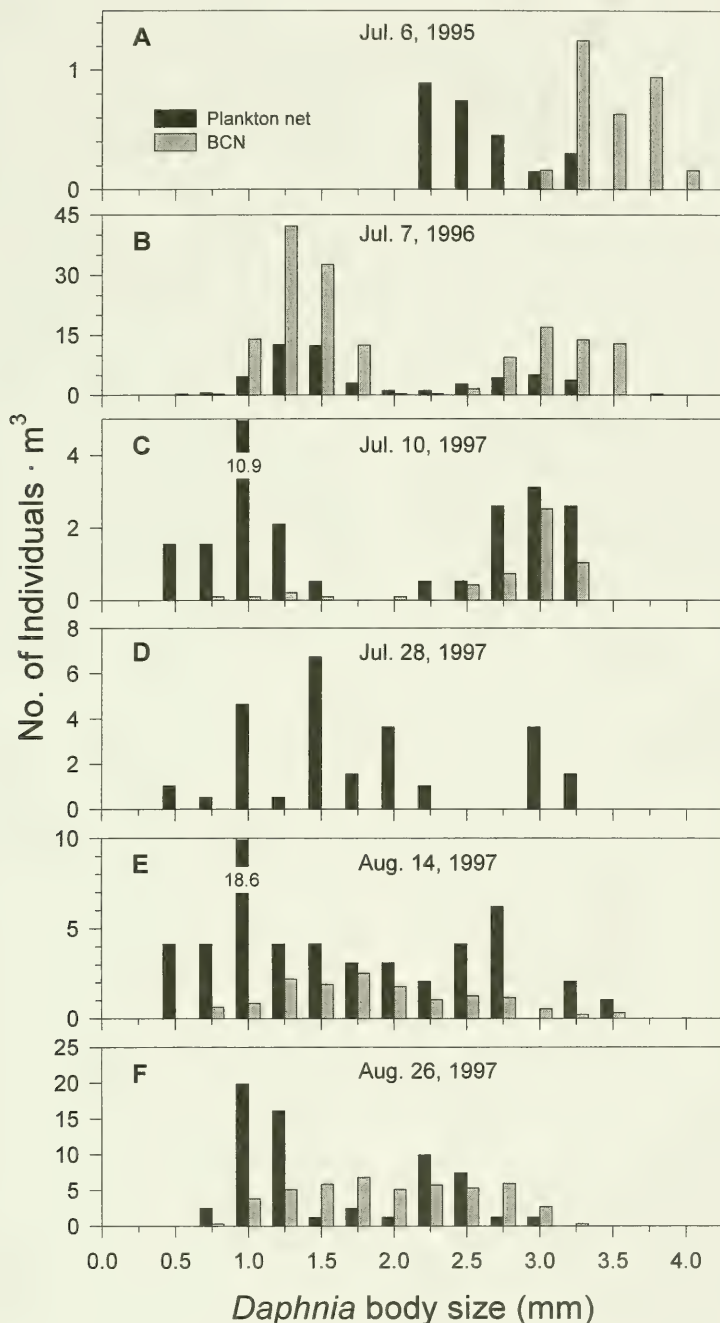


FIGURE 1. Size distributions of *Daphnia middendorffiana* from Pipit Lake, Alberta, Canada. Plankton net tows were initiated 1 m above the bottom of the lake while bottom closing net (BCN) hauls sampled the entire water column and the top sediment layers. In 1995 (A) and 1996 (B), large *D. middendorffiana* (up to 4.0 mm) were collected from the bottom 1 m of the lake. In 1997 (C-F), a large cohort was also present but only few individuals in July (C) and August (E) larger than the largest *Daphnia* in the plankton hauls were retrieved with the BCN. The large cohort could be distinguished until August 14 (E) at which time ephippia production commenced, indicating the large *Daphnia* cohort persisted through at least 2/3 of the open-water season. BCN hauls were not taken on 28 July 1997 because of mechanical malfunctions.

Results and Discussion

In 1995, a single *Daphnia* cohort was present in Pipit Lake (Figure 1A). The mean size of the pelagic *Daphnia* collected with the plankton net from the water column was $2.6 \text{ mm} \pm 0.08 \text{ SE}$ ($n = 17$), while the largest individual measured 3.2 mm. Similar sized *Daphnia* were also present in the BCN sample in addition to the large profundal *Daphnia*. Because we sampled only the upper 19 m of the water column with the plankton net, the large *Daphnia* collected with the BCN must have come from the bottom meter of the water column. The largest *Daphnia* collected with the BCN in 1995 was 4.0 mm ($\bar{x} = 3.6 \text{ mm} \pm 0.06 \text{ SE}$, $n = 15$, only individuals $> 3.2 \text{ mm}$ included). Although our 6 July 1995 collections were made during daylight hours, only a single 3.6 mm *Daphnia* was collected above 19 m during night zooplankton vertical migration studies on 5 and 28 July, 1995 (Hardie, unpublished data), indicating that the occurrence of large *Daphnia* above 19 m is rare. Prepas and Rigler (1978) reported a similar spatial separation of *D. pulex* in Crawford Lake, Ontario, composed of a migrating upper population and a non-migrating deep population.

In 1996, two *Daphnia* cohorts were present in Pipit Lake after ice-out (Figure 1B). Similar to 1995, large *Daphnia* exceeding the largest individuals from plankton tows were present in the BCN samples, indicating they came from the bottom 1 m of the water column. The mean size of the large cohort collected with the plankton net was $2.9 \text{ mm} \pm 0.03 \text{ SE}$ ($n = 110$, only individuals $> 2.25 \text{ mm}$ included, Figure 1B), while the largest individual measured 3.4 mm. The mean size of the 42 *Daphnia* larger than 3.4 mm collected with the BCN was $3.5 \text{ mm} \pm 0.01 \text{ SE}$, with the largest individual measuring 3.7 mm.

In 1997, similar to 1996, two *Daphnia* cohorts were present on 10 July shortly after ice-out (Figure 1C). The mean size of the large cohort collected in the plankton tows was $2.9 \text{ mm} \pm 0.06 \text{ SE}$, $n = 18$ and the largest *Daphnia* measured 3.32 mm. Only two individuals slightly larger (3.36 mm) were captured in the BCN samples, perhaps indicating the absence of extremely large individuals from the lake this year. However, because sampling was carried out at only one station in the lake, the lack of large individuals in the sample could be the result of patchy *Daphnia* distribution, since *Daphnia* are generally not evenly distributed in their environment.

Our data show that the presence of a large *Daphnia* cohort (mean size 2.6 - 3.0 mm) is a common occurrence in Pipit Lake shortly after ice-out. Due to the lack of high numbers of large *Daphnia* exceeding the largest size collected in the plankton tows in 1997, we are unable to conclusively demonstrate the persistence of profundal *Daphnia* throughout the entire open-water season. However, the presence of the large cohort until mid-August (Figure

1D), after which ephippia production commenced, suggests some individuals survive. In fact, similar to the 10 July 1997 collection, two individuals slightly larger (3.48 and 3.56 mm) than the largest (3.40 mm) net tow *Daphnia* were collected in the BCN hauls on 14 August 1997. These low numbers of large *Daphnia* are probably due to a slow decline in the large cohort through the open-water season. However, at the same time they indicate that some individuals survive through at least 2/3 of the open-water season. Additionally, the occurrence of large *Daphnia* in the bottom 1 m of the water column during this time supports our suggestions that the large *Daphnia* are residents of the profundal region of Pipit Lake.

1995 Gut content and stable nitrogen analysis

We observed mainly algal remains and crushed pollen grains in the guts of the pelagic *Daphnia*, whereas the intestinal tracts of the profundal *Daphnia* contained detritus, *Hesperodiaptomus* eggs, nauplii, charcoal particles and some algae. The pelagic *Daphnia* had a $\delta^{15}\text{N}$ of -0.3‰ compared to 4.2‰ for the profundal *Daphnia*, while the $\delta^{15}\text{N}$ of the POM and sediment was 2.2 and 2.4‰ respectively.

The large range in the $\delta^{15}\text{N}$ between the profundal and pelagic *Daphnia* is similar to the -2‰ to $+9\text{‰}$ reported for primary consumers from 14 Ontario Lakes (Vander Zanden and Rasmussen, Department of Biology, McGill University, unpublished data). Such variability in nitrogen stable isotopic values is thought to arise from the availability of $\delta^{15}\text{N}$ enriched pools of inorganic N resulting from nitrogen transformation processes such as denitrification and ammonification which predominate in profundal zones of stratified lakes. Therefore, primary consumers from the profundal region of lakes would have higher $\delta^{15}\text{N}$ values than pelagic organisms. The large difference in the $\delta^{15}\text{N}$ of the two *Daphnia* samples also suggests that the large *Daphnia* are profundal residents.

The low $\delta^{15}\text{N}$ of the pelagic *Daphnia* in relation to POM does not correspond to the expected 3.4‰ increase between trophic levels (Peterson and Fry 1987; Kling et al. 1992) and indicates they assimilate some isotopically light fraction. This highlights the difficulty of interpreting trophic position using POM as a base reference since it is a mixture of food sources, and different foods can differ in isotopic composition. For example, algal species differ in isotopic composition (Montoya 1990 cited in Kling et al. 1992), and isotopically light species have been reported from both lakes and streams (Fry 1991). The algal component of POM from several alpine lakes in the vicinity of Pipit Lake is isotopically much lighter than the general POM in those lakes (Hardie, unpublished data).

The $\delta^{15}\text{N}$ enrichment of the profundal *Daphnia* (2.0 and 1.8‰ in relation to POM and sediment respectively) is also less than the 3.4‰ expected between trophic levels. Sediment, similar to POM, is also a mixture of food sources which differ in isotopic composition. Gu et al. (1994) measured highly variable $\delta^{15}\text{N}$ values for different sediment size fractions in a subarctic lake. Selection of an isotopically light fraction by the profundal *Daphnia* could have resulted in the lower than expected $\delta^{15}\text{N}$. The similarity in $\delta^{15}\text{N}$ between POM and sediment does not permit us to distinguish the food source of the profundal *Daphnia*. Nevertheless, the prevalence of detritus, *Hesperodiaptomus* eggs, and nauplii in their guts leads us to believe that they feed mainly on bottom sediment. Sediment browsing by *Daphnia* is known to occur in periods of food shortage (Horton et al. 1979; Lampert 1987). The profundal *Daphnia* may not be food limited, but may be using Pipit Lake sediment as their regular food source instead. Abundant *Hesperodiaptomus* eggs (up to 65 000 eggs $\cdot \text{m}^{-2}$ Parker et al. 1996) and associated hatched nauplii in surficial sediment in Pipit Lake would be encountered frequently by browsing *Daphnia*. Because of their high lipid content, eggs and nauplii may be selected by these *Daphnia*. We have observed eggs and nauplii in *Daphnia* guts from other alpine lakes in the vicinity of Pipit Lake and Dodson (1975) reported that *D. middendorffiana* from a shallow arctic pond ingested *Heterocope septentrionalis* nauplii, suggesting this phenomenon is not a rare occurrence. Our gut content and stable nitrogen isotope analyses indicate that only certain fractions of the food which can be distinguished in the gut are assimilated.

Given the widespread distribution of *D. middendorffiana*, it is surprising that we are the first to report such large individuals. Large *D. middendorffiana* may be present in other lakes but are probably overlooked because standard plankton sampling techniques do not adequately sample near the sediment-water interface. This results in an under representation of suprabenthic organisms such as the large *Daphnia* in plankton samples. In addition, planktonic species which undergo diurnal vertical migrations, such as *Chaoborus* which occupy the top sediment layer during daylight hours, may also be missed or incompletely sampled. We recommend researchers use a variety of sampling gear to ensure that their samples adequately represent resident lake zooplankton populations.

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Selection of Candidate Species of Freshwater Mussels (Bivalvia: Unionidae) to be Considered for National Status Designation by COSEWIC

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Severe declines in the diversity and abundance of freshwater mussels have been documented over the past century in the United States. Although similar trends might be expected in Canada, mussels (and in fact invertebrates in general) have received little attention to date. This imbalance was first addressed in 1994 when the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) expanded its mandate to include invertebrates. A Mollusc Working Group (MWG) was formed in 1995 to determine the status of Canadian mollusc species at risk. The first task of the MWG was to prepare a preliminary list of candidate species to be considered for national status designation by COSEWIC. In this paper, a risk factor analysis approach was used to identify the most imperiled species of freshwater mussels in the Canadian waters of the lower Great Lakes drainage basin. This region was chosen because it historically supported the most diverse and unique mussel fauna in Canada. Species were evaluated on the basis of their current conservation status ranks, distribution patterns, vulnerability to Zebra Mussels, host specificity and evidence of decline over time in the study area. A database of over 4100 occurrence records for 40 species collected between 1860 and 1996 was compiled for this purpose. Results showed that nearly 40% of these species would likely fall into the Extirpated, Endangered or Threatened risk categories as defined by COSEWIC. A prioritized list of nine species was proposed for national status designation by COSEWIC.

Key Words: Unionidae, freshwater mussels, endangered species, COSEWIC, Great Lakes.

North America is the world centre for the evolutionary radiation of freshwater bivalves (Barr 1996*), and the greatest diversity of freshwater mussels, nearly 300 species, occurs on this continent (Williams et al. 1993). Over the past century, this rich fauna has been decimated by commercial harvesting of mussels (initially for the pearl button industry, and of late for the cultured pearl industry), habitat destruction, water pollution and, most recently, the invasion of the exotic Zebra Mussel *Dreissena polymorpha* (Biggins et al. 1995*). In a recent assessment by the American Fisheries Society (Williams et al. 1993), 72% of native freshwater mussel species were listed as extinct, endangered, threatened or of special concern and only 24% as currently stable. Similarly, The Nature Conservancy recognizes 55% of the mussel fauna as imperiled, in contrast to only 7% of birds and mammals (Master 1990). No other widespread animal group in North America approaches this level of faunal collapse.

The vulnerability of native freshwater mussels to anthropogenic impacts can be attributed in part to a unique life history trait: they have an intermediate larval stage that is an obligate ectoparasite on fish (Neves 1993). Female mussels brood their young from the egg to the larval stage in their gills, then expel the larvae, termed glochidia, into the water where they must attach to the gills or fins of an appropriate fish host in order to complete their metamorphosis. After a period of encystment ranging from 1 to 25 weeks, depending on the species (Cummings and Mayer 1992), the juvenile mussel detaches from its host and falls to the substrate to complete its development into a free-living adult. Some species may successfully use a variety of fishes, but the majority are host-specific to some degree (Neves 1993). It is largely because of this dependency that mussels are so sensitive to perturbations of the freshwater ecosystem (Bogan 1993). Not only are they threatened by disturbances that impact them directly, but also by those that affect their host fish populations. In several cases, mussel species have become functionally extinct, i.e., known only from non-reproductive populations, due to the disappearance of host fish (Bogan 1993).

*See Documents Cited section, between Acknowledgments and Literature Cited.

According to Williams et al. (1993), the most significant cause of the decline of freshwater mussels during the last century is the destruction of their habitat by siltation, dredging, channelization, the creation of impoundments, and pollution. In some cases, dams have resulted in the loss of 30% to 60% of the mussel fauna, mainly due to the elimination of host fish. Erosion due to deforestation, poor agricultural practices and the destruction of riparian zones leads to an increase in siltation and shifting substrates that can smother mussels. As noted by Bogan (1993), domestic sewage; effluents from paper mills, tanneries, chemical industries and steel mills; acid mine runoff; heavy metals and pesticides have all been implicated in the destruction of the mussel fauna.

While factors such as these have been causing the reduction and extirpation of mussel populations for many years (Nalepa and Gauvin 1988), the recent introduction of the Zebra Mussel to the Great Lakes has led to catastrophic declines of native mussels in infested areas (Gillis and Mackie 1994). Zebra Mussels attach to the shells of mussels and interfere with normal activities such as feeding, respiration and burrowing (Nalepa et al. 1996). Ricciardi et al. (1996) postulate that Zebra Mussels kill native mussels by robbing them of the energy reserves they need to survive the winter. Zebra Mussels have decimated native mussel populations in Lake St. Clair (Nalepa et al. 1996), western Lake Erie (Schloesser and Nalepa 1994) and the upper St. Lawrence River (Ricciardi et al. 1996).

In the United States, freshwater mussels have been protected under endangered species legislation since 1969 (Neves 1993). The U.S. Fish & Wildlife Service recently drafted a national strategy for the conservation of native mussels (Biggins et al. 1995*), and recovery plans are in place for 42 of their 57 listed species (U.S. Fish and Wildlife Service 1996). It wasn't until 1994 that the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) expanded its mandate to include invertebrates. A Subcommittee was formed in 1995 to address two of the best-studied groups of invertebrates, namely, the Lepidoptera (the moths and butterflies) and the Mollusca (which includes freshwater mussels). The mandate of COSEWIC is to develop a national list of Canadian wildlife species at risk and to prepare status reports on these species (Cook and Muir 1984). Recovery plans for the species most at risk are then prepared and implemented under the Recovery of Nationally Endangered Wildlife (RENEW) strategy. At present, only terrestrial vertebrates listed by COSEWIC in the extirpated, endangered and threatened categories are considered under RENEW; plants, fish, marine mammals, invertebrates and all species in the vulnerable category fall outside of RENEW's mandate (Theresa Aniskowicz, Canadian Wildlife Service,

personal communication, November 1997). In 1997, the Mollusc Working Group of the Lepidoptera and Mollusca Subcommittee submitted status reports on two species of molluscs; the Gatineau Tadpole Snail (*Physella parkeri latchfordi*) was designated in the indeterminate category, and the Banff Springs Snail (*Physella johnsoni*) was designated as threatened.

The purpose of this paper is to contribute to the development of a list of freshwater mussel species to be considered for national status designation by COSEWIC. A risk factor analysis approach was used. The geographical focus was on the lower Great Lakes drainage basin for three reasons. First of all, this area historically supported the most diverse mussel fauna in Canada; 40 of the 53 Canadian species occur here, and 21 of these are found nowhere else in Canada (see Clarke 1981). The Lake Erie and Lake St. Clair drainages in particular are home to the richest mussel fauna in the country. Secondly, Zebra Mussels have decimated native mussels in the lower Great Lakes, leaving the rivers and streams of the drainage basin as the last refuge for many species. Finally, this region has suffered "...some of the most intense human habitat exploitation in all of Canada" (Barr 1996*). It is clear that conservation measures are urgently needed to maintain and recover these unique components of aquatic biodiversity.

Materials and Methods

Study Area

The study area consisted of the lower Great Lakes, i.e., Lake St. Clair, Lake Erie, and Lake Ontario, their connecting rivers, and all watersheds draining into the lakes within the boundaries of the Province of Ontario (Figure 1a).

Selection of Candidate Species for Consideration by COSEWIC

Five risk factors were considered in the selection of candidate species: (1) their current global, North American and provincial conservation status ranks; (2) their distribution, i.e., whether widespread or restricted; (3) their vulnerability to Zebra Mussels, i.e., the proportion of their range that falls within Zebra Mussel-infested waters; (4) their degree of host specificity, where known; and (5) evidence that the species has declined in occurrence or relative dominance over time in the study area. Information required for the assessment of factors 1 and 4 was readily available from various agencies or the published literature. Assessment of factors 2, 3 and 5 required the synthesis of all available historical and recent data on the occurrences of freshwater mussel species throughout the study area into a database, which was then used to generate species distribution maps and evaluate trends over time for each species.

The Lower Great Lakes Unionid Database

Data sources included the primary literature, natur-

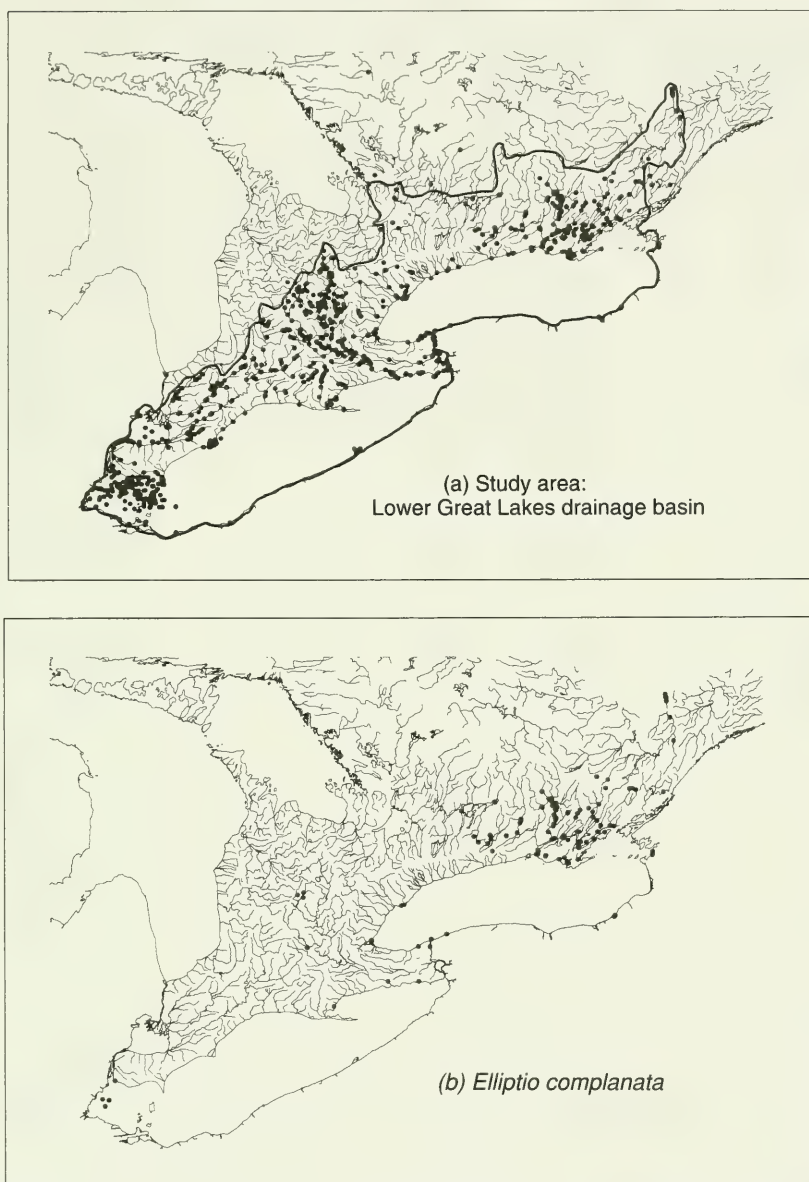


FIGURE 1. (a) Map of the study area showing the locations where freshwater mussels (Unionidae) were collected between 1860 and 1996, based on data from natural history museums and other sources. (b) Distribution of *Elliptio complanata* in the lower Great Lakes drainage basin, based on historical data.

ral history museums, federal, provincial and municipal government agencies (and some American agencies), conservation authorities, Remedial Action Plans for the Great Lakes Areas of Concern, university theses, and environmental consulting firms. Mollusc collections held by natural history museums in the Great Lakes region were the primary sources of information, accounting for over two-thirds of the

data acquired. The only records available in computerized format were those of the Ohio State University Museum of Zoology (OSUMZ). Records from the Canadian Museum of Nature (CMN) were computerized at our request, and included all uncatalogued material from the study area. Data from the Rochester Museum and Science Center (RMSC) were available in hard copy. Data from the Royal Ontario Museum

TABLE 1. Species of freshwater mussels (Unionidae) found in the lower Great Lakes drainage basin between 1860 and 1996. Nomenclature after Williams et al. (1993).

Subfamily	Scientific name	Common name
Ambleminae (Button Shells)	<i>Amblema plicata plicata</i>	Threeridge
	<i>Cyclonaias tuberculata</i>	Purple Pimpleback
	<i>Elliptio complanata</i>	Eastern Elliptio
	<i>Elliptio dilatata</i>	Spike
	<i>Fusconaia flava</i>	Pigtoe
	<i>Quadrula pustulosa pustulosa</i>	Wartyback
	<i>Quadrula quadrula</i>	Mapleleaf
	<i>Pleurobema coccineum</i>	False Pigtoe
Anodontinae (Floater Mussels)	<i>Alasmidonta marginata</i>	Elktoe
	<i>Alasmidonta undulata</i>	Heavy-toothed Wedge Mussel
	<i>Alasmidonta viridis</i>	Brook Wedge Mussel
	<i>Anodontoides ferussacianus</i>	Cylindrical Floater
	<i>Lasmigona complanata complanata</i>	White Heelsplitter
	<i>Lasmigona compressa</i>	Brook Lasmigona
	<i>Lasmigona costata</i>	Fluted Shell
	<i>Pyganodon cataracta</i>	Eastern Floater
	<i>Pyganodon grandis</i>	Common Floater
	<i>Simpsonaias ambigua</i>	Mudpuppy Mussel
	<i>Strophitus undulatus</i>	Squawfoot
	<i>Utterbackia imbecillis</i>	Paper Pondshell
Lampsilinae (Lamp Mussels)	<i>Actinonaias ligamentina</i>	Mucket
	<i>Epioblasma torulosa rangiana</i>	Northern Riffleshell
	<i>Epioblasma triquetra</i>	Snuffbox
	<i>Lampsilis fasciola</i>	Wavy-rayed Lampmussel
	<i>Lampsilis ovata</i>	Pocketbook
	<i>Lampsilis radiata radiata</i>	Eastern Lampmussel
	<i>Lampsilis siliquioidea</i>	Fat Mucket
	<i>Leptodea fragilis</i>	Fragile Papershell
	<i>Ligumia nasuta</i>	Pointed Sandshell
	<i>Ligumia recta</i>	Black Sandshell
	<i>Obliquaria reflexa</i>	Threehorned Wartyback
	<i>Obovaria olivaria</i>	Olive Hickorynut
	<i>Obovaria subrotunda</i>	Round Hickorynut
	<i>Potamilus alatus</i>	Pink Heelsplitter
	<i>Ptychobranhus fasciolaris</i>	Kidneyshell
	<i>Toxolasma parvus</i>	Lilliput Mussel
	<i>Truncilla donaciformis</i>	Fawnsfoot
	<i>Truncilla truncata</i>	Deertoe
	<i>Villosa fabalis</i>	Rayed Bean
	<i>Villosa iris</i>	Rainbow Shell

(ROM), Buffalo Museum of Science (BMS) and University of Michigan Museum of Zoology (UMMZ) were obtained directly from the collections, i.e., from the catalogue books and/or labels stored with the specimens themselves. For many species, the nomenclature has changed several times over the years. This can be particularly problematic when dealing with old museum records. A synonymy was developed to address this problem. Taxonomy was standardized to the nomenclature most recently adopted by the Freshwater Mussels Subcommittee of the American Fisheries Society Endangered Species Committee (Williams et al. 1993).

Very few of the data from any source had been geo-referenced, therefore coordinates (latitude and

longitude) were assigned to collection sites based on descriptions of site locations. This was necessary in order to prepare species distribution maps. Coordinates were assigned using 1:50 000 Energy, Mines, and Resources Canada topographical maps. In some cases, coordinates were generated using the software package TYDAC SPANS® Map™ Version 1.4 on digital base maps provided by the Geomatics Office of Environment Canada, Burlington, Ontario. The database was created using the software program Microsoft® Access Version 7.0, and contains fields for information such as: data source, name of collector, collection date, name of waterway, primary drainage, description of sampling location, geographical coordinates, genus and species, number of

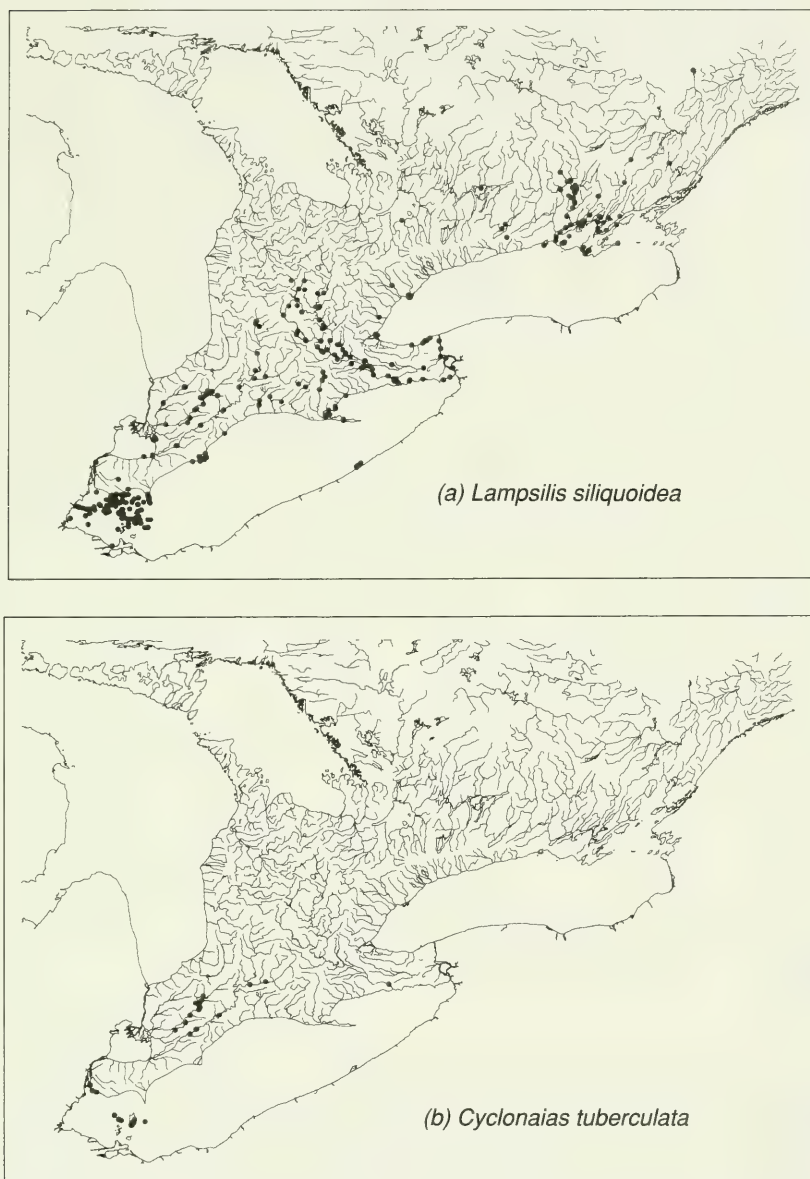


FIGURE 2. Distributions of: (a) *Lampsilis siliquoidea* and (b) *Cyclonaias tuberculata* in the lower Great Lakes drainage basin, based on historical data.

specimens collected live vs. dead, and number of species collected at a given site.

The database currently consists of over 4100 records collected from approximately 1500 sites between 1860 and 1996. A record is defined as the occurrence of a given species at a given location on a given date. The locations of all collection sites represented in the database are shown in Figure 1a. It is apparent that rivers and streams draining into central and western Lake Ontario have been sampled the

least intensively. A total of 40 species of mussels belonging to three subfamilies of the Family Unionidae (Anodontinae, Ambleminae and Lampsilinae) have been reported from the study area (Table 1). The Family Margaritiferidae is not represented in the basin. As Clarke (1981) is the recognized authority on freshwater mussels in Canada, it may be helpful to identify instances where the taxonomy in Table 1 differs from that of Clarke. The differences are as follows, with Clarke's nomenclature

TABLE 2. Conservation status ranks and categories for freshwater mussel species.

	Definitions
Provincial (NHIC) and global (The Nature Conservancy) ^a	
SH	Historical; of only historical occurrence in the province or globally (no occurrences verified in the past 20 years)
S1/G1	Extremely rare; usually 5 or fewer occurrences in the province (or globally)
S2/G2	Very rare; usually between 5 and 20 occurrences
S3/G3	Rare to uncommon; usually between 20 and 100 occurrences
S4/G4	Common; usually more than 100 occurrences
S5/G5	Very common; demonstrably secure under present conditions
North American (American Fisheries Society) ^b	
E	Endangered; a species or subspecies in danger of extinction throughout all or a significant portion of its range
T	Threatened; a species or subspecies that is likely to become endangered throughout all or a significant portion of its range
SC	Special concern; a species or subspecies that may become endangered or threatened by relatively minor disturbances to its habitat, and deserves careful monitoring of its abundance and distribution
U	Undetermined; a species or subspecies whose historic and current distribution and abundance has not been evaluated in recent years
CS	Currently stable; a species or subspecies whose distribution and abundance may be stable, or it may have declined in portions of its range but is not in need of immediate conservation management actions
COSEWIC ^c	
X	Extinct; a species that no longer exists
XT	Extirpated; a species no longer existing in the wild in Canada, but occurring elsewhere
E	Endangered; a species facing imminent extirpation or extinction
T	Threatened; a species likely to become endangered if limiting factors are not reversed
V	Vulnerable; a species of special concern because of characteristics that make it particularly sensitive to human activities or natural events
NAR	Not at Risk; a species that has been evaluated and found to be not at risk
I	Indeterminate; a species for which there is insufficient scientific information to support status designation

^aD. A. Sutherland, NHIC, personal communication, December 1996^bWilliams et al. (1993)^cCOSEWIC (1996*)

appearing first: *Amblesma plicata* = *Amblesma plicata plicata*; *Quadrula pustulosa* = *Quadrula pustulosa pustulosa*; *Lasmigona complanata* = *Lasmigona complanata complanata*; *Anodonta cataracta cataracta* = *Pyganodon cataracta*; *Anodonta grandis grandis* = *Pyganodon grandis*; *Simpsoniconcha ambigua* = *Simpsonaias ambigua*; *Anodonta imbecilis* = *Utterbackia imbecilis*; *Actinonaias carinata* = *Actinonaias ligamentina*; *Dysnomia tortulosa rangiana* = *Epioblasma tortulosa rangiana*; *Dysnomia triquetra* = *Epioblasma triquetra*; *Lampsilis ventricosa* = *Lampsilis ovata*; *Lampsilis radiata siliquoidea* = *Lampsilis siliquoidea*; *Proptera alata* = *Potamilus alatus*; *Carunculina parva* = *Toxolasma parvus*.

Historical data such as these, which were collected over a long period of time for various unrelated purposes by different people using different sampling methods, are rife with inconsistencies. The database

contained the following inconsistencies relevant to this study: (1) *Collection sites not adequately described*. For some collection sites, geographical coordinates could not be assigned precisely or occasionally not at all due to insufficient information. Data for which no coordinates could be assigned had to be excluded from species distribution maps. (2) *Collection dates missing*. Collection dates were missing from many of the older museum records. As these records were considered too valuable to omit, "most probable" collection dates were assigned based on the period during which the collector was active. In cases where an individual did most of his or her collecting within a single decade, for example, the first year of the decade was arbitrarily assigned to the record. As the majority of missing collection dates were well before the cut-off date of 1960 used in the time-trend analysis, these estimates would have no effect on interpretation. (3) *Whether speci-*

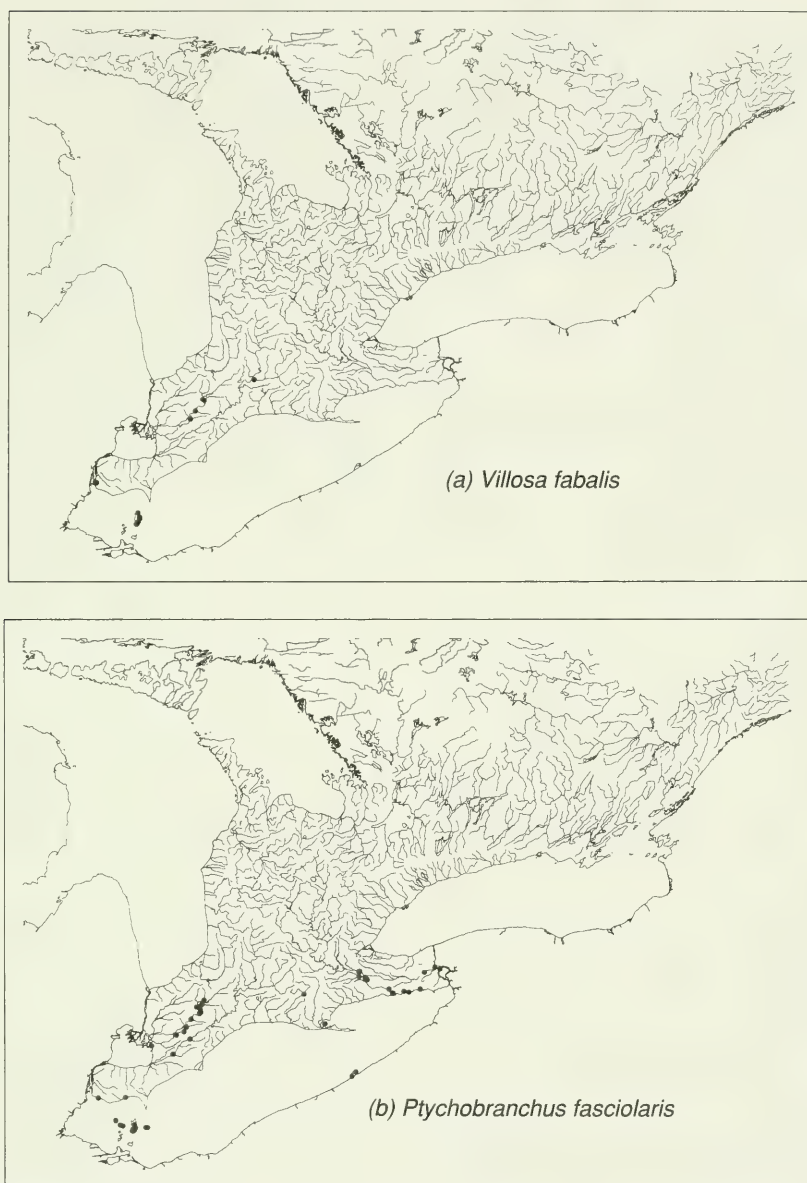


FIGURE 3. Distributions of: (a) *Villosa fabalis* and (b) *Ptychobranchus fasciolaris* in the lower Great Lakes drainage basin, based on historical data.

mens live or dead at time of collection not noted. With the exception of the OSUMZ, the museums did not have information on whether the specimens in their collections had been collected live or dead. Some other data sources, especially the academic surveys of recent years, did make this distinction. For the purpose of this study, all records, whether of live or dead specimens, were treated equally. Because mussel shells may persist in relatively good condition in the environment for years after their

inhabitants have died, this approach could underestimate the number of species that declined in occurrence over time in the study area. (4) *Sampling effort variable.* Sampling effort varied greatly from amateurs picking up a few shells for their collections to Ph.D. students conducting intensive sampling for their thesis research, and this has serious implications for conducting time-trend analysis with the data. A measure of sampling effort was usually available for the academic surveys, most of which

took place after 1960. However, no information of this nature was available for the museum specimens, which constituted the major portion of the data. Intuitively, one would expect academic surveys to involve greater efforts than collections by amateurs. Two facts support this hypothesis: the percentage of sites where only one species was collected was higher before 1960 (60%) than after 1960 (40%); and there were twice as many records after 1960 as before, even though only 17% more sites were sampled.

Results and Discussion

Species Distributions

Distribution maps displaying all known occurrences of each species between 1860 and 1996 were prepared, and the complete set is available from the authors. These maps include over 1200 new records collected since the most recent synopsis of species distributions was published (Clarke 1981). With the exception of *Alasmidonta undulata*, the 40 species listed in Table 1 as occurring in the lower Great Lakes drainage basin were also reported from this region by Clarke (1981). According to Clarke (1981), *A. undulata* is known in Canada from Nova Scotia and the St. Lawrence River; however, four recent records for this species from the Trent-Severn Waterway were found during the present study. Although museum records for *Anodonta implicata* (the Alewife Floater) were also found within the study area, they were considered erroneous since this species is not known to the Great Lakes region (Clarke 1981). This conclusion is supported by Strayer and Jirka (1997), who noted in their review of the pearly mussels of New York State that most museum collections contained specimens identified as *A. implicata* that were in fact large, atypical variations of *Pyganodon* spp. The original identifications had been made before malacologists were able to differentiate between these similar species.

The distributions of freshwater mussel species are a consequence of their post-glacial re-invasion routes, which followed those of their host fish (Barr 1996*). Based on Mandrak and Crossman's (1992) description of the dispersal patterns of freshwater fishes in Ontario, Barr (1996)* divided the current ranges of freshwater mussels into two basic distribution patterns: primarily southwestern and primarily northeastern. According to Barr's (1996)* rationale, the majority of species found to occur in the study area during the present study are southwestern (Mississippian) in origin, whereas five species are northeastern (Atlantic Coastal), and one (*Strophitus undulatus*) may have re-invaded via both routes. *Elliptio complanata* (Figure 1b) is the most common northeastern species in the study area; the other four species (*Alasmidonta undulata*, *Lampsilis radiata radiata*, *Obovaria olivaria* and *Pyganodon cataracta*) are mainly found in the Atlantic drainage

where all except *O. olivaria* are still common. In his discussion of contemporary distribution patterns of unionids within the Mixedwood Plains Ecozone (which includes the Lake Huron, Lake Erie, Lake Ontario, Ottawa River, and St. Lawrence River basins), Barr (1996)* characterized three range types: local (species occupying no more than 30% of the zone), widespread (species occupying 30% to 80% of the zone), and pan-regional (species occupying more than 80% of the zone). Some species, such as *Lampsilis siliquoidea* (Figure 2a), are widespread, but the majority, such as *Cyclonaias tuberculata* (Figure 2b) were found to have local ranges. Barr (1996)* concluded that the freshwater mussel fauna of the Mixedwood Plains Ecozone consists primarily of species with local distributions, centred in southwestern Ontario.

Selection of Candidate Species for Consideration by COSEWIC

As noted earlier, five risk factors were considered in the selection of candidate species. Not all factors were given equal emphasis. Conservation status ranks (Factor 1) and evidence of decline over time (Factor 5) were considered to be the most important factors, because they are based on a large body of information. Vulnerability to Zebra Mussels (Factor 3) and distribution pattern (Factor 2) were considered to be less important because they are coarse and somewhat subjective. Host specificity (Factor 4) was given the least emphasis because the data are incomplete for many species. Each factor is discussed in detail below.

Factor 1 — Conservation status ranks

Conservation status ranks or categories are available for the mussel species of interest from three sources, namely, The Nature Conservancy (global), the American Fisheries Society (North America) and the Natural Heritage Information Centre [NHIC] (Ontario). The ranking systems used by each source are described in Table 2. The risk categories used by COSEWIC are included for comparison. The Nature Conservancy and the NHIC are affiliated and use identical ranking systems. Otherwise, each organization uses somewhat different criteria to determine risk, such that their systems cannot necessarily be equated. The NHIC is in the process of developing a list of rare and endangered species of flora and fauna for the Province of Ontario, and its current conservation status ranks for Ontario freshwater mussels are known to be based on fewer data than those included in our database (D. A. Sutherland, Zoologist, NHIC, personal communication, June 1997).

Ranks assigned to a given species by the global (The Nature Conservancy) and North American (American Fisheries Society) systems generally agreed. For example, all species ranked as CS (currently stable) in North America were globally ranked as G4 to G5 (common to very common), and the two

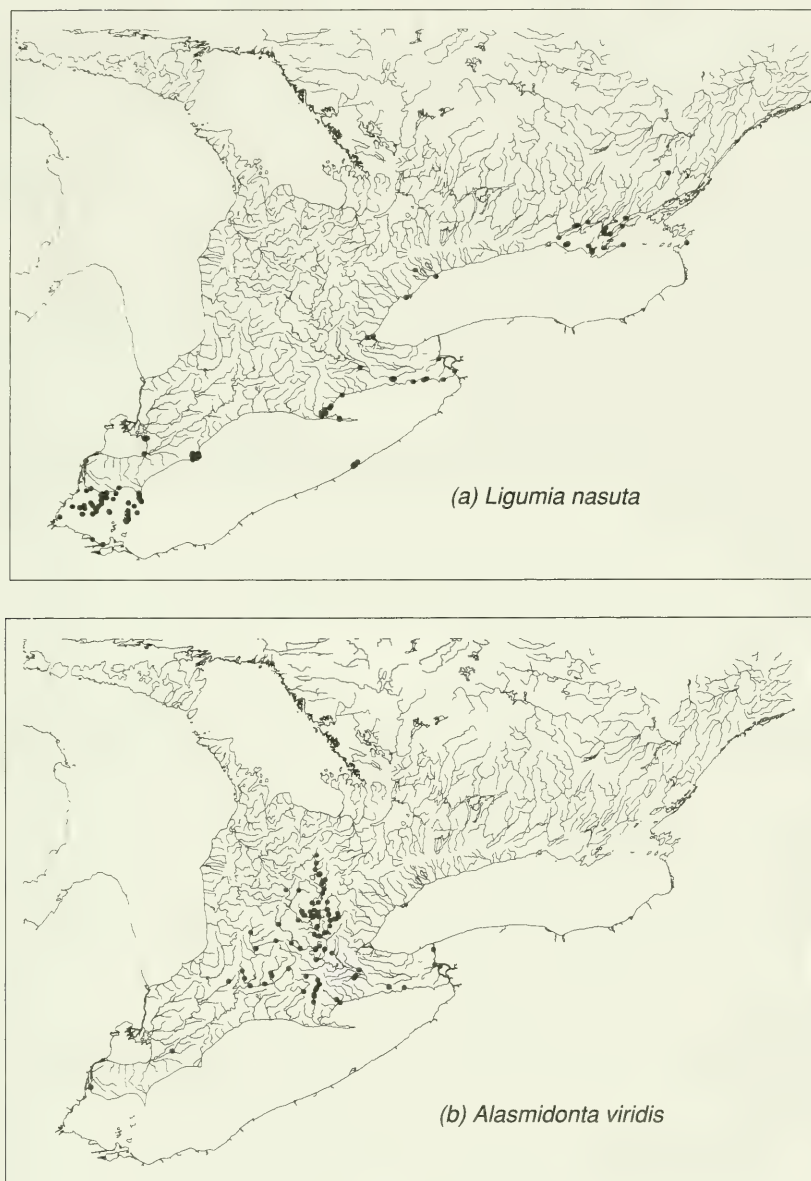


FIGURE 4. Distributions of: (a) *Ligumia nasuta* and (b) *Alasmidonta viridis* in the lower Great Lakes drainage basin, based on historical data.

species ranked as E (endangered) and T (threatened) in North America were globally ranked as G2 and G3 (very rare and rare, respectively). However, 8 of the 11 species considered to be of special concern (SC) in North America were globally ranked as very common, even though they are only found in North America. The reason for this difference is not known, but it may be that the North American ranks are based on more recent information than the global ranks. There were more obvious discrepancies

between the Ontario (NHIC) ranks and the other ranks. The reason for this is that many species native to the study area are at the northern periphery of their range (Barr 1996*), and are naturally less common here. It should also be noted that some species that are rare in Ontario may in fact be common elsewhere in Canada. For example, the northeastern species *Alasmidonta undulata* and *Pyganodon cataracta*, which are ranked as S2 to S3 in Ontario, are known to be common in the Atlantic drainage

TABLE 3. Categorization of freshwater mussel species most at risk based on evidence of decline in the study area.

Species	Direction of change based on				Direction of change based on				Risk category ^b
	Before 1960 # occurrences	After 1960 # occurrences	Before 1960 % of records	After 1960 % of records	Before 1960 % of records ^a	After 1960 % of sites	Before 1960 % of sites	After 1960 % of sites	
<i>Alasmidontia undulata</i>	3	1	0.22	0.04	-	0.44	0.44	0.13	1
<i>Elliptio complanata</i>	83	83	6.07	3.01	-	12.22	12.22	10.41	1
<i>Epioblasma torulosa rangiana</i>	5	4	0.37	0.15	-	0.74	0.74	0.50	1
<i>Epioblasma triquetra</i>	14	13	1.02	0.47	-	2.06	2.06	1.63	1
<i>Ligumia nasuta</i>	71	67	5.19	2.43	-	10.46	10.46	8.40	1
<i>Obovaria olivaria</i>	11	1	0.73	0.04	-	1.47	1.47	0.13	1
<i>Pyganodon cataracta</i>	16	4	1.17	0.15	-	2.36	2.36	0.50	1
<i>Lampsilis siliquioidea</i>	194	238	14.18	8.64	-	28.57	28.57	29.86	2
<i>Pleurobema coccineum</i>	28	35	2.05	1.27	-	4.12	4.12	4.39	2
<i>Simpsoniata ambigua</i>	2	2	0.15	0.07	-	0.29	0.29	0.25	2
<i>Truncilla donaciformis</i>	13	18	0.95	0.65	-	1.91	1.91	2.26	2
<i>Villosa fabalis</i>	6	7	0.44	0.25	-	0.88	0.88	0.88	2
<i>Lampsilis radiata radiata</i>	56	86	4.09	3.12	-	8.25	8.25	10.80	3
<i>Alasmidontia viridis</i>	30	72	2.19	2.61	=	4.42	4.42	9.03	4
<i>Anodontoides ferussacianus</i>	36	71	2.63	2.58	=	5.30	5.30	8.91	4
<i>Fusconaia flava</i>	47	99	3.44	3.59	=	6.92	6.92	12.42	4
<i>Lampsilis fasciola</i>	7	14	0.51	0.51	=	1.03	1.03	1.76	4
<i>Lampsilis ovata</i>	69	121	5.04	4.39	=	10.16	10.16	15.19	4
<i>Lasmigona costata</i>	65	129	4.75	4.68	=	9.57	9.57	16.19	4
<i>Leptodea fragilis</i>	77	131	5.63	4.76	=	11.34	11.34	16.44	4
<i>Ligumia recta</i>	42	78	3.07	2.83	=	6.19	6.19	9.79	4
<i>Potamilus alatus</i>	57	102	4.17	3.70	=	8.39	8.39	12.80	4
<i>Quadrula quadrula</i>	21	46	1.54	1.67	=	3.09	3.09	5.77	4
<i>Obliquaria reflexa</i>	10	22	0.73	0.80	=	1.47	1.47	2.76	4
<i>Utterbackia imbecillis</i>	5	9	0.37	0.33	=	0.74	0.74	1.13	4
<i>Villosa iris</i>	28	54	2.05	1.96	=	4.12	4.12	6.78	4
<i>Actinonaias ligamentina</i>	20	58	1.46	2.11	+	2.95	2.95	7.28	5
<i>Alasmidontia marginata</i>	16	68	1.17	2.47	+	2.36	2.36	8.53	5
<i>Amblema plicata plicata</i>	41	113	3.00	4.10	+	6.04	6.04	14.18	5
<i>Cyclonaias tuberculata</i>	10	40	0.73	1.45	+	1.47	1.47	5.02	5
<i>Elliptio dilatata</i>	54	131	3.95	4.76	+	7.95	7.95	16.44	5
<i>Lasmigona complanata complanata</i>	1	58	0.07	2.11	+	0.15	0.15	7.28	5
<i>Lasmigona compressa</i>	34	108	2.49	3.92	+	5.01	5.01	13.55	5
<i>Obovaria subrotunda</i>	13	32	0.95	1.16	+	1.91	1.91	4.02	5

(Continued)

TABLE 3. Concluded.

Species	Direction of change based on			Direction of change based on			Risk category ^b
	Before 1960 # occurrences	After 1960 # occurrences	Before 1960 % of records	After 1960 % of records	Before 1960 % of sites	After 1960 % of sites	
<i>Ptychobranchius fasciolaris</i>	17	47	1.24	1.71	2.50	5.90	5
<i>Pyganodon grandis</i>	111	355	8.11	12.89	16.35	44.54	5
<i>Quadrula pustulosa pustulosa</i>	16	40	1.17	1.45	2.36	5.02	5
<i>Sirophitus undulatus</i>	24	134	1.75	4.87	3.53	16.81	5
<i>Toxolasma parvus</i>	2	7	0.15	0.25	0.29	0.88	5
<i>Truncilla truncata</i>	14	56	1.02	2.03	2.06	7.03	5
Total # records	1369	2754					
Total # sites	679	797					

^a“+” sign indicates a significant increase and a “-” sign indicates a significant decrease in occurrence over time; a 20% difference is considered significant.
^bcategory 1 is most at risk and category 5 is least at risk for this factor.

(Clarke 1981) and are therefore not significantly at risk from COSEWIC’s national perspective.

Factor 2 — Distribution Patterns

Species with restricted distributions are considered to be more at risk than those that are more widespread. As noted earlier, 21 of the 40 species occur only in southern Ontario (considering their Canadian distributions only). An additional six species are also found in the Red-Assiniboine drainage in Manitoba, where their current status is not known (James Duncan, Manitoba Conservation Data Centre, personal communication, November 1996). All species were assigned to one of three risk categories based on their distributions across Canada. According to Barr (1996)*, 60% of the freshwater mussel species in the Mixedwood Plains Ecozone have ranges that would be described as “local”. However, there are “degrees” of local. For example, *Villosa fabalis* (Figure 3a) is known mainly from the Sydenham River and around Pelee Island in Lake Erie, whereas *Ptychobranchius fasciolaris* (Figure 3b) is known from Lake Erie, Lake St. Clair and several of their major tributaries. Species with very restricted ranges are particularly vulnerable to loss, because a disturbance in a single watershed could have serious consequences for the species as a whole. All species were assigned values of 1 (very localized) to 5 (widespread) to indicate their range characteristics, as determined from the distribution maps.

Factor 3 — Vulnerability to Zebra Mussels

Zebra Mussels pose a major threat to the survival of native freshwater mussels in the study area. Species that occur mainly in the Great Lakes themselves or in the lower reaches of the larger tributaries, e.g., *Ligumia nasuta* (Figure 4a), are most at risk from the impact of Zebra Mussels. In contrast, headwater species such as *Alasmidonta viridis* (Figure 4b) are unlikely to encounter the Zebra Mussel throughout most of their ranges. All species were assigned to one of three risk categories based on their vulnerability to Zebra Mussels, as determined from the distribution maps.

Factor 4 — Host Specificity

Information on the numbers of recognized fish hosts for each species was obtained from two recent review papers (Hoggarth 1992; Watters 1994). Only those fish hosts known to occur in the study area (see Scott and Crossman 1973) were included. According to Neves (1993), some degree of host specificity appears to be the rule rather than the exception for most freshwater mussel species. Clearly, any change in the abundance or species composition of the fish fauna could have serious effects on recruitment in co-dependent populations of unionids. Not surprisingly, the most common mussel species are those that have many suitable fish hosts. For example, *Pyganodon grandis* and *Lampsilis siliquoidea*, which

TABLE 4. Results of the risk factor analysis used to identify and prioritize candidate species of freshwater mussels to be considered for national status designation by COSEWIC. Group 1 species are most at risk and Group 3 species are least at risk.

Group	Species	Conservation status ranks ^a			Distribution patterns		Vulnerability to Zebra Mussels ^d	Number of fish hosts	Evidence of decline ^e
		Ontario	North American	Global	Distribution ^b	Range ^c			
1	<i>Epioblasma torulosa rangiana</i>	SH	E	2	1	1	2	N/A	1
	<i>Epioblasma triquetra</i>	SH	T	3	1	2	1	1	1
	<i>Simpsoniata ambigua</i>	SH	SC	2	1	1	3	1	2
	<i>Obovaria olivaria</i>	SH	CS	4	3	3	1	N/A	1
	<i>Toxolasma parvus</i>	SH	CS	4	1	2	3	3	5
	<i>Obliquaria reflexa</i>	SH	CS	5	1	2	1	N/A	4
2	<i>Villosa fabalis</i>	1	SC	2	1	1	2	N/A	2
	<i>Truncilla donaciformis</i>	1.5	CS	4	1	2	1	2	2
	<i>Pleurobema coccineum</i>	2	CS	3.5	1	2	2	1	2
	<i>Ligumia nasuta</i>	3	SC	4	1	3	1	N/A	1
	<i>Lampsilis fasciola</i>	1	CS	4	1	2	3	1	4
	<i>Unierbackia imbecillis</i>	1	CS	5	1	2	1	9	4
	<i>Cyclonaias tuberculata</i>	1	SC	5	1	1	2	N/A	5
	<i>Obovaria subrotunda</i>	1	SC	3	1	2	2	N/A	5
	<i>Psychobanchus fasciolaris</i>	1	CS	4	1	2	1	N/A	5
	<i>Truncilla truncata</i>	1.5	CS	4	1	2	2	2	5
	<i>Actinonaias ligamentina</i>	2	SC	5	1	3	3	12	5
	<i>Quadrula pustulosa pustulosa</i>	2	CS	5	1	2	2	4	5
	<i>Quadrula quadrula</i>	2	CS	5	2	4	2	N/A	4
	<i>Alasmidonta viridis</i>	3	SC	4	1	3	3	2	4
3	<i>Alasmidonta marginata</i>	3	SC	5	1	4	3	4	5
	<i>Ligumia recta</i>	3	SC	5	2	4	2	8	4
	<i>Alasmidonta undulata</i>	2.5	SC	5	3	4	3	N/A	1
	<i>Pyganodon cataraacta</i>	2	CS	5	3	4	3	4	1
	<i>Potamilus alatus</i>	3	CS	5	2	4	1	1	4
	<i>Villosa iris</i>	3	CS	4	1	3	3	3	4
	<i>Ambleria plicata plicata</i>	3	CS	5	2	4	2	12	5
	<i>Fusconia flava</i>	3	CS	5	2	4	2	3	4
	<i>Lasmsgona complanata complanata</i>	3	CS	5	3	5	2	5	5
	<i>Lampsilis ovata</i>	4	SC	5	3	5	3	7	4
	<i>Leptodea fragilis</i>	4	CS	5	1	4	1	1	4
	<i>Lasmsgona costata</i>	4	CS	5	2	4	3	1	4
	<i>Elliptio dilatata</i>	4	CS	5	3	4	2	5	5
	<i>Lampsilis radiata radiata</i>	4	CS	5	3	5	2	6	3
	<i>Strophitus undulatus</i>	4	CS	5	3	5	3	4	5

(Continued)

TABLE 4. Concluded.

Group	Species	Conservation status ranks ^a			Distribution patterns		Vulnerability to Zebra Mussels ^d	Number of fish hosts	Evidence of decline ^e
		Ontario	North American	Global	Distribution ^b	Range ^c			
	<i>Lasmigona compressa</i>	5	CS	5	3	5	3	N/A	5
	<i>Elliptio complanata</i>	5	CS	5	3	5	3	5	1
	<i>Anodonta imbecillis</i>	5	CS	5	3	5	3	9	4
	<i>Lampsilis siliquoidea</i>	5	CS	5	3	5	3	14	2
	<i>Pyganodon grandis</i>	5	CS	5	3	5	3	31	5

^asee Table 2 for definitions
^b1 = southwestern Ontario only; 2 = southwestern Ontario and Red-Assiniboine drainage in Manitoba only; 3 = also occurs elsewhere in Canada
^c1 to 5 = very localized to widespread
^d1 = very vulnerable; 2 = somewhat vulnerable; 3 = not vulnerable
^efrom Table 3

are the dominant mussel species in the study area, have the most known hosts (31 and 14, respectively). Conversely, 10 of the 11 species for which no hosts have yet been identified are species ranked SH, S1 or S2 in Ontario. Of the 29 species for which at least some hosts have been identified, fully one-third have only one or two known hosts.

Although host specificity was not one of the major factors considered in the selection of candidate species, it has implications for a few species. *Utterbackia imbecillis* and *Actinonaias ligamentina* have large numbers of hosts (9 and 12, respectively), including common species such as Largemouth Bass (*Micropterus salmoides*), Smallmouth Bass (*Micropterus dolomieu*), Bluegill (*Lepomis macrochirus*) and Yellow Perch (*Perca flavescens*), yet their provincial ranks are S1 and S2. This suggests that these mussel species are being limited by factors acting on them directly rather than on the fish community that supports them. Conversely, *Lasmigona costata* and *Leptodea fragilis* both rank S4, despite having only one known fish host each. The explanation for this is that their hosts are two of the most widespread and abundant species in the study area, namely, the Carp (*Cyprinus carpio*) and the Freshwater Drum (*Aplodinotus grunniens*), respectively. As Carp is an introduced species (Scott and Crossman 1973), *L. costata* undoubtedly has other hosts. No hosts have been identified for *Obovaria olivaria* in Canada; however, it is known to use the Shovelnose Sturgeon (*Scaphirhynchus platyrhynchus*) elsewhere. The most likely host for this species in Canada is the Lake Sturgeon (*Acipenser fulvescens*), which is one of the St. Lawrence Action Plan's priority wildlife species (Bouchard and Millet 1993*) mainly due to the small number of spawning adults that now exist. If the Lake Sturgeon suffers further declines, *O. olivaria* could become functionally extinct.

Factor 5 — Evidence of Decline in the Study Area

To assess this factor, the database was examined for changes in the occurrence of each species over time. The data were divided into two time periods, with the "historical" time period defined as before 1960 and the "recent" time period defined as after 1960. The choice of 1960 as the cut-off date was somewhat arbitrary, but was influenced by the occurrence of similar numbers of sampling sites in both periods (679 and 797, respectively). A more detailed time-trend analysis, i.e., over a series of shorter time periods, was precluded by the limitations of the data that were described earlier.

The available data can be analyzed in two ways to evaluate trends over time for individual species. Changes in relative dominance, i.e., the proportion of total records accounted for by each species in each time period, indicate whether a certain species has increased, decreased or stayed the same in terms

of its significance in the community. The difficulty with this type of analysis is that some species may only appear to have decreased in occurrence because others have substantially increased. This approach could therefore *overestimate* the number of species for which declines have actually occurred. Another way to examine the data was to compare the proportion of sites at which a given species was found before and after 1960. This analysis assumes that sampling effort was the same in both time periods, when in fact sampling effort increased considerably after 1960 (as noted earlier). It is conceivable that a species found at 5% of the sites in both time periods actually declined, because more time was spent searching for it after 1960. This approach could therefore *underestimate* the number of species for which declines have actually occurred. The results of both types of analysis were considered together to determine risk. For example, species that declined based on both proportions of records and proportions of sites were considered most at risk (category 1), those that declined based on proportions of records but did not change based on proportions of sites were assigned to category 2, etc. A 20% increase or decrease was considered to be significant. The results are presented in Table 3.

Final Selection and Prioritization of Candidate Species

Results of the risk factor analysis used to identify and prioritize candidate species of mussels to be considered for national status designation by COSEWIC are presented in Table 4. The 40 species were separated into three groups based on their overall level of risk, with Group 1 containing the species considered to be most at risk and Group 3 containing those least at risk. Within each group, species were arranged in order from most to least at risk based, in many cases, on subjective decisions concerning the significance of various risk factors for individual species.

Group 1 contains the six species that are presumed extirpated from Ontario by the NHIC (no live specimens verified in the past 20 years). As the ranges of all species except *Obovaria olivaria* are confined to Ontario, these species would also be presumed extirpated from Canada. As *O. olivaria* has likely been extirpated from the core of its range (the St. Lawrence River; Clarke 1981) by Zebra Mussels, it also belongs in Group 1. It should be noted that the present database contains one record for a live specimen of *Toxolasma parvus* collected from the Sydenham River in 1991 (Clarke 1992) and one record for a live specimen of *Epioblasma triquetra* collected from Lake St. Clair in 1983 (Griffiths 1987*), so it is possible that these two species are extant. Four of the six species had also exhibited significant declines in occurrence since 1960, and there were fewer than 20 records after this date for all except *Obliquaria reflexa*. As 17 relatively fresh

whole shells of the latter species were collected from the lower Grand River by D. J. Berg, University of Toronto, Mississauga, Ontario, in 1988 (ROM collection), it is arguable whether this species should remain in Group 1 or be moved to Group 2.

All of the species assigned to Group 2 ranked from S1 to S2 in Ontario except for *Ligumia nasuta*, which is currently ranked S3. The ranges of all Group 2 species are restricted to Ontario. As *L. nasuta* has significantly declined, is extremely vulnerable to Zebra Mussels, and was once a major component of the mussel community (fifth largest number of records of any species prior to 1960), we gave it a higher priority than the NHIC. *Villosa fabalis* was assigned the highest priority in this group mainly due to its global rank of G2. Although the database contains only seven records for this species since 1960, four were for live specimens collected from the Sydenham River in 1967 (OSUMZ collection), 1971 (Clarke 1972) and 1991 (Clarke 1992). *Truncilla donaciformis* and *Pleurobema coccineum* rank S1/S2 and S2, respectively, in Ontario, but were given a higher priority than the remaining Group 2 species because they had shown the greatest declines over time.

Prioritization of species in Group 3 generally followed the Ontario conservation status ranks. Other factors were used to determine the order of priority among species within a particular Ontario rank. For example, *Potamilis alatus* was placed ahead of four other S3 species because of its vulnerability to Zebra Mussels, *Lampsilis ovata* was given a higher priority than other S4 species because it is of special concern in North America, and the five S5 ranked species were prioritized according to their numbers of fish hosts. Most species in Group 3 fell into categories 4 or 5 for Factor 5, indicating that they had not declined or had in fact increased in occurrence over time in the study area. However, five species fell into categories 1 (*Alasmidonta undulata*, *Pyganodon cataracta*, *Elliptio complanata*), 3 (*Lampsilis radiata radiata*) or 2 (*Lampsilis siliquoidea*). Evidence of decline was not considered in the prioritization of these five species for the following reasons: Results for the first four species, which are northeastern in origin, are believed to be spurious because only one-third as many sites in the Lake Ontario drainage were sampled before 1960 as after 1960. It should be cautioned that the national conservation status of these and many other Group 3 species cannot be properly determined until their status in the other regions of Canada where they occur is known. *Lampsilis siliquoidea* is one of the most common and widespread species of freshwater mussel in Canada and is therefore not currently at risk. However, indications are that it is being replaced as the dominant species of unionid in the lower Great Lakes drainage basin by *P. grandis* (J. L. Metcalfe-

Smith et al., in preparation). Because this species is obviously an important functional component of the mussel community in Canada, it's course should be tracked. *Lasmigona complanata complanata* was found at one site prior to 1960 and 58 sites after 1960, suggesting that it may be expanding its range and could possibly be considered for down-listing in the future.

As the six Group 1 species are the most at risk, it seems reasonable that they should be given first priority for national status designation by COSEWIC. Listing extinct and extirpated species is important, because it draws attention to the fact that serious problems exist, may encourage activities to rehabilitate the habitats of these species such that future reintroductions might be possible, and lends urgency to efforts on behalf of species that have not quite reached the critical stage (Theresa Aniskowicz, Canadian Wildlife Service, personal communication, November 1997). From a practical conservation point of view, however, it may be more important for the Mollusc Working Group of COSEWIC to focus its efforts on officially designating those species for which there may still be time to intervene, i.e., the species in Group 2.

Conclusions

A risk factor analysis approach was used to identify candidate species of freshwater mussels to be considered for national status designation by COSEWIC. Based on this analysis, 15 of the 40 species of freshwater mussels native to the Canadian waters of the lower Great Lakes drainage basin would likely fall into the Extirpated, Endangered or Threatened risk categories as defined by COSEWIC. These are the species listed in Groups 1 and 2 of Table 4. Group 1 species are not recommended as candidates for listing by COSEWIC at the present time, because it is our contention that there is less to be gained from documenting the status of species that are already presumed extirpated than from officially designating those species that may follow a similar path unless measures are taken soon to conserve and protect them. Only those species that have been officially listed by COSEWIC are eligible for funding under the Endangered Species Recovery Fund, which is administered by the World Wildlife Fund Canada, for the development and implementation of recovery plans. We therefore recommend that the nine species in Group 2 be given first consideration for national status designation by COSEWIC, in the following order of priority: *Villosa fabalis*, *Truncilla donaciformis*, *Pleurobema coccineum*, *Ligumia nasuta*, *Lampsilis fasciola*, *Utterbackia imbecillis*, *Cyclonaias tuberculata*, *Obovaria subrotunda*, and *Ptychobranchus fasciolaris*. The results of this study should be viewed as a first attempt to identify the mussel species most at risk in Canada,

and we hope that it will stimulate further discussion and refinement.

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Distribution of Small Mammals Among Successional and Mature Forest Types in Western Labrador

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The effects of secondary succession following forest fire on vegetation structure and small mammal populations were determined on ten sites near Labrador City (Newfoundland, Canada). Study plots represented six successional stages and one fen. The abundance of small mammals on plots increased with the successional age of the plot. The Boreal Red-backed Vole, *Clethrionomys gapperi* was the most common small mammal species while the Meadow Vole, *Microtus pennsylvanicus*, the Heather Vole, *Phenacomys intermedius*, and the Masked Shrew, *Sorex cinereus*, were restricted in distribution. *C. gapperi* was positively associated with trees > 2 m high and broad leaved shrubs 0.5 m high while negatively associated with lichens. *M. pennsylvanicus* was positively associated with grasses/sedges and negatively associated with trees ≤ 2 m high. *P. intermedius* was positively associated with downed woody debris. *S. cinereus* was negatively associated with grasses/sedges and positively associated with broadleaved shrubs ≤ 0.5 m high. Some correlations among the abundances of small mammals and habitat variables may not reflect cause and effect relationships: *C. gapperi*'s negative association with lichen and *S. cinereus*'s negative association with grasses/sedges.

Key Words: Boreal Red-backed Vole, *Clethrionomys gapperi*, Meadow Vole, *Microtus pennsylvanicus*, Heather Vole, *Phenacomys intermedius*, Masked Shrew, *Sorex cinereus*, secondary succession, Labrador.

Forest fires and clear-cut logging are the major large scale disturbances of the boreal forest (Hunter 1990). Relatively little logging has been conducted in Labrador. Forest management planners, however, expect to greatly increase the amount of logging in Labrador (Forestry Canada 1994). Because subsurface soil temperatures remain cool except where fire is intense (Bradley et al. 1992), fossorial mammals often escape fires unharmed. Later, however, small mammals may suffer mortality from losses of required food and cover. Secondary succession following fire, therefore, while not precisely duplicating the effects of logging, can be used to provide initial predictions of logging effects.

Secondary successional sites in northern forests should support increased numbers of small mammals with increased successional age. Early successional sites should be dominated by granivores, grass and sedge bearing plots should support foliovores, and sites dominated by trees should support omnivores (Fox 1983). However, site specific patterns of small mammal population change often depend on geographic location (Sullivan and Sullivan 1982; Fox 1983; Swan et al. 1984). Climatic differences, which make it difficult to predict vegetation succession (Starfield and Chapin 1996), may also contribute to site specific variations in the structure of small mam-

mal populations (Fox 1983). Competition among small mammal species may influence the effect that site disturbance has on the composition and dynamics of small mammal communities (Payne 1974; Crowell and Pimm 1976). The present study investigates the effects of secondary succession following wildfire upon the structure of plant communities and associated small mammal populations in western Labrador.

Study Area

The study area is located in the Low Subarctic Ecoclimate Region (Canada Committee on Ecological Land Classification 1989: pages 15, 16, and 20). Mesic sites are dominated by open stands of Black Spruce (*Picea mariana*) with understories of Dwarf Birch (*Betula glandulosa*), Labrador Tea (*Ledum groenlandicum*), lichen (mostly *Cladina* spp.) and moss. Ten 2.35 ha study plots were located within 12 km of Labrador City, Newfoundland (52°57' N, 67°42' W).

The 10 study plots included two recent, 3-year-old, burns (3a and 3b); two older, 20-year-old, burns (20a and 20b); one old, 40-year-old, burn (40); three mature coniferous forests of the following ages: 110 (110), 130 (130) and 150 (150) years old; one 150 year old deciduous forest (D150) and one fen

TABLE 1. Crown coverage (%) of major vegetation groups by sample site.

Plot	Trees ^a > 2 m	Trees ^b ≤ 2 m	Broad L. Shrubs ^c ≤ 0.5 m		Grass/ Sedge	Herbs ^d	Woody Debris	Moss ^e	Lichen ^f
3a	—	0.14	0.33		0.14	0.02	0.02	—	0.01
3b	—	0.16	0.38		0.21	0.14	0.06	0.17	—
20a	0.16	0.12	0.44		0.02	0.39	0.15	0.43	0.19
20b	0.12	0.44	0.61		0.04	0.04	0.03	0.49	0.16
40	0.09	0.50	0.38		0.04	—	0.10	0.23	0.69
110	0.43	0.11	0.37		—	0.01	0.01	0.76	0.03
130	0.80	0.16	0.20	T ¹	0.01	0.04	0.04	0.97	0.13
150	0.59	0.22	0.56		0.03	0.05	0.03	0.59	0.03
D150	0.83	0.19	0.66		0.01	0.43	0.06	0.13	—
Fen	—	0.10	0.19		0.19	0.17	—	0.61	—

¹T denotes a crown coverage $> 0 < 0.001$.

^aIncludes: *Abies*, *Betula*, *Picea*.

^bIncludes: *Alnus*, *Abies*, *Betula*, *Picea*, *Salix*.

^cIncludes: *Cornus*, *Ledum*, *Linnaea*, *Potentilla*, *Vaccinium*.

^dIncludes: *Dryopteris*, *Epilobium*, *Equisetum*.

^eIncludes: *Pleurozium*, *Dicranum*, *Ptilium*, *Sphagnum*.

^fIncludes: *Cladina*, *Peltigera*.

(Table 1). Fens, although not an environment modified by fire, may serve as a dispersal reservoir if a fire occurs in the surrounding forest. Therefore, we wished to determine small mammal occupancy of these potentially important habitats.

Methods

Trapping

Ten trap stations were established at 15 m intervals along ten parallel transects 15 m apart, producing 100 trap stations on a 10 × 10 grid. At each station two Victor snap-traps were placed within 1 m of the station marker in the microsite offering the most visual cover that did not interfere with the trapping mechanism. Traps were baited with a mixture of rolled oats, peanut butter, bacon fat, and honey. Sites were prebaited for one night and trapped for four nights. Traps were checked before 9:00 am from 26 July to 4 September, 1995. Trapped mammals were identified according to pelage and dental characteristics (Banfield 1977). Sex and weight of specimens were also recorded.

Vegetation

The coverage of trees was estimated using a system adapted from Emlen (1967). The presence of tree species was recorded above systematically placed points. Trees included all *Alnus*, *Abies*, *Betula*, *Larix*, *Picea* and *Salix* species. Broad-leaved shrubs ≤ 0.5 m, downed woody debris, and ground vegetation were estimated using a system adapted from Daubenmire (1968). Low broad-leaved shrubs included all *Cornus*, *Ledum*, *Linnaea*, *Potentilla*, and *Vaccinium* species. Ground vegetation included mosses, forbs, and prostrate shrubs (woody plants

except those listed above). The coverage of ground vegetation within a 0.1 m² frame was recorded in one of seven percentage classes: 0, 0-5, 5-25, 25-50, 50-75, 75-95, 95-100. The midpoints of these classes were the data used in the analyses.

On plots 3a, 20a, and fen, the coverage of tree species was determined using the trap station markers as the Emlen points for a total of 100 points. Twenty-five Daubenmire frames were placed on every fourth station marker.

The remaining plots were within 10-ha bird census study plots established by us. The vegetation descriptions for the larger bird plots were used to characterize the trapping grids. The vegetation characteristics on the more open plots, 3b, 20b and 40 were described on 5 sub-transects perpendicular and alternating in direction placed at 50 m intervals from a transect bisecting the plot's long axis. Emlen points (n = 400) were recorded at 2 m intervals along each sub-transect. Daubenmire frames (n = 80) were placed at 10 m intervals along each sub-transect. On the heavily forested successional stages, 110, 130, 150 and D150, three 20 × 20 m subplots were systematically located on each plot. Vegetation characteristics were estimated on five parallel transects running across subplots 4 m apart. Emlen points (n = 300) were recorded at 1 m intervals along all five transects. Daubenmire frames (n = 60) were placed at 5 m intervals along each transect.

Most of the larger bird study plots were homogeneous for the successional age described and the vegetation data were suitable for the terrestrial mammal plots at the same location. The exceptions were plots 3b, 20b and D150 where sub-transects or subplots

ran through atypical areas. On plot 20b, for example, a sub-transect ran through an area dominated by 4 m tall White Birch (*Betula papyrifera*), where the area within the trapping grid was dominated by 2 to 3 m tall Dwarf Birch and willow (*Salix* spp.). Data from atypical sub-transects or subplots were not used in the vegetation descriptions.

Statistical analysis

Statistical analysis was carried out using the S-plus statistical package version 3.3 for unix (StatSci 1993). The trapping effort for each site was equal; therefore, the number of animals captured on each plot was used as the index of relative abundance. Because count data frequently follow a poisson distribution, small mammals were related to vegetation characteristics with a poisson regression linked to a log_e function using the Generalized Linear Model (McCullagh and Nelder 1989). An analysis of deviance with a Chi-square was used to test whether a predictor significantly reduced the null deviance.

Results

Small mammal density generally increased with age of succession (Table 2). The Boreal Red-backed Vole (*Clethrionomys gapperi*) was found on all sites but the fen and was most abundant on the older successional sites. The Meadow Vole (*Microtus pennsylvanicus*) was most abundant on the fen but a few occurred on the recent burns. The Heather Vole (*Phenacomys intermedius*) was most abundant on one older burn (20a), but was rare or absent on other sites. The Masked Shrew (*Sorex cinereus*) was most abundant on a mature conifer site (150), common on an older burn (20a), but rare or absent on all other sites. *Clethrionomys gapperi* was positively associated with trees > 2 m high ($p < 0.001$) and with broadleaved shrubs ≤ 0.5 m high ($p < 0.001$) but negatively correlated with lichens ($p < 0.01$). *Microtus pennsylvanicus* was positively associated with grasses/sedges ($p < 0.001$) and negatively associated with trees ≤ 2 m high ($p < 0.05$). Downed woody debris was a positive predictor of *P. intermedius* ($p < 0.001$). *Sorex cinereus*

was negatively correlated with grasses/sedges ($p < 0.001$) and positively correlated with broadleaved shrubs ≤ 0.5 m high ($p < 0.05$).

Discussion

In general, small mammal density increased with succession. Foliovores (*M. pennsylvanicus* and *P. intermedius*) were common on plots supporting grasses and sedges. Forest plots were dominated by the omnivore *C. gapperi*. Despite the occurrence of the Deer Mouse (*Peromyscus maniculatus*) in Labrador (Fox 1983; Banfield 1977), they were not found in this study. Small mammals were least abundant on one older burn (20b) and the old burn (40). Both sites were dry and supported few herbs, grasses or berries for small mammal food. As dryness delays log decay, and decaying logs are often used for cover by small mammals (Tallmon and Mills 1994), the low numbers of small mammals on those sites could be expected.

As forests age, trees die leaving gaps in the forest canopy. Fallen trees provide woody debris used for foraging, nesting, travel and navigation by small mammals (Tallmon and Mills 1994). Sunlight reaching the forest floor through canopy gaps stimulates understory growth. Sunlight and a generally moist soil combine to provide abundant cover, nest sites, food and water for small mammals in older forests.

Clethrionomys gapperi is attracted to older moist forest, hence the positive associations between *C. gapperi* and trees > 2 m high and broad-leaved shrubs ≤ 0.5 m high. And, its negative association with lichens. These results agree with Reichel (1986), Clough (1987), and Nordyke and Buskirk (1991). The importance of fallen logs to *C. gapperi* (Tallmon and Mills 1994) was illustrated by one trap-line on a coniferous forest plot (130) that was adjacent to large downed woody debris, and produced 10 of 17 total captures. A moist microclimate, visual cover, food and large woody debris are reasons for the positive associations between *C. gapperi* and trees ≤ 2 m and broadleaved shrubs ≤ 0.5 m high.

TABLE 2. The numbers of small mammals captured by site (number per 100 trapnights).

Site	<i>C. gapperi</i>	<i>M. pennsylvanicus</i>	<i>P. intermedius</i>	<i>S. cinereus</i>
3a	2 (0.25)	4 (0.50)	2 (0.25)	—
3b	7 (0.88)	5 (0.63)	1 (0.13)	—
20a	6 (0.75)	1 (0.13)	10 (1.25)	4 (0.50)
20b	4 (0.50)	—	—	—
40	1 (0.13)	—	—	—
110	12 (1.50)	—	—	—
130	17 (2.13)	—	—	1 (0.13)
150	36 (4.50)	—	—	10 (1.25)
D150	51 (6.38)	1 (0.13)	1 (0.13)	1 (0.13)
Fen	—	14 (1.75)	—	—
Total	136 (1.70)	25 (0.31)	14 (0.18)	16 (0.20)

The negative association between *C. gapperi* and lichens may be caused by the quantity of lichens on drier more open sites (see Table 1), lacking features attractive to *C. gapperi*.

Our positive association of *M. pennsylvanicus* with grass/sedges and the negative association with trees ≤ 2 m high agrees with other studies (Crowell and Pimm 1976; Krebs and Wingate 1976; Parker 1989). Grasses and sedges are an important food for *M. pennsylvanicus* (Riewe 1973). The suppression of grass and sedge growth by trees ≤ 2 m high may have caused that negative correlation.

Microtus pennsylvanicus captured on the fen were on or near hummocks. Since the dominant shrub on hummocks was *Potentilla*, a species rarely eaten by Meadow Voles (Riewe 1973), hummocks were probably not used as foraging sites. These sheltered sites may be used for nesting and cover from which forays are made to areas containing grasses and sedges (Payne 1974).

Phenacomys intermedius prefers open dry habitats containing ericaceous shrubs (Krebs and Wingate 1976; Taylor et al. 1985). We captured *P. intermedius* almost exclusively on one older burn (20a) where those characteristics were common. This site also contained many large rocks, a feature also associated with *P. intermedius* microhabitat (Reichel 1986). *Phenacomys intermedius* may have been attracted to downed woody debris. But, that positive association could also have been due to coincident habitat features. *Phenacomys intermedius* was likely attracted to the Low Bush Blueberry (*Vaccinium angustifolium*), Labrador Tea (*Ledum groenlandicum*), and rock microenvironments that were most common on site 20a which also contained the most downed woody debris.

The apparent negative association between *S. cinereus* and grasses/sedges was likely due to that species response to moisture. *Sorex cinereus* prefers mesic sites (Banfield 1977) and was not captured on the driest plots, recent burns (3a and 3b), one older burn (20b) and the old burn (40), where grasses were common, nor the wettest plot (fen), where sedges were common. An intermediate moisture environment, however, was provided by a shrub-covered environment, thus the positive correlation between *S. cinereus* and broad-leafed shrubs ≤ 0.5 m high.

No previous study has examined the relationship between forest structure and small mammals in Labrador. This study demonstrates that small mammals respond predictably to secondary succession following forest fire: Small mammal numbers increase with successional age. The distribution of small mammal populations among habitat types are predictable and dependant upon species specific habitat requirements. If the effects of forest fires and logging are similar enough, then logging effects on Labrador small mammals can be predicted using their habitat requirements.

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Nocturnal Foraging Behaviour of Black Bears, *Ursus americanus*, on Moresby Island, British Columbia

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Black Bears (*Ursus americanus*) are usually active during daylight but are known to shift to crepuscular and nocturnal activity when daylight activities are disrupted. The principle factors currently thought to promote this shift are the presence of Brown Bears (*U. arctos*) and humans. I examined the extent of diurnal, crepuscular and nocturnal activity of Black Bears in an estuary and stream during salmon spawning migration at Bag Harbour, Haida Gwaii, off coastal British Columbia. A predominance of daylight activity was predicted as there are no Brown Bears on Haida Gwaii and only minimal human disturbance in the remote area. Results show that during daylight, there was low but consistent foraging activity in the stream but no daylight foraging on the estuary even when salmon were abundant. Bears were intolerant of each other during daylight and would rarely forage within visual range of each other. Use of night-viewing goggles show that most foraging on the stream and all foraging on the estuary occurred during darkness with peak activity four to six hours after sunset. Up to six bears foraged simultaneously in the shallows in close proximity to each other with few agonistic interactions. High foraging success during darkness occurred because salmon showed reduced evasive responses to shoreline disturbance compared with daylight. These observations suggest that occasional nocturnal activity by Black Bears on the mainland of western North America might be the result of preferred foraging periods rather than disturbance with diurnally active competitors.

Key Words: Black Bear, *Ursus americanus*, salmon, nocturnal, foraging behaviour, Queen Charlotte Islands, British Columbia.

Black Bears (*Ursus americanus*) are primarily diurnal both in eastern and western North America (Lindzey and Meslow 1977; Larivière et al. 1994; Powell et al. 1997). Vision is presumably important in the behavioural interactions among bears as well as in the search for food, which is highly diverse (Powell et al. 1997; Matchutcheon et al. *in press*). Black Bears are also active during darkness, for example, where the species overlaps with Brown Bear (*U. arctos*) and where human activities are prevalent during daylight (Olson et al. *in press*). This shift to nocturnal activity occurs in western North America and is interpreted as an ecological restriction to less preferred foraging periods (Matchutcheon et al. *in press*; Olson et al. *in press*). Yet in a study of Alaskan Black Bear on an estuary with migrating salmon, Frame (1974) found a predominance of crepuscular foraging despite the absence of Brown Bears and absence of human disturbance in the area. This suggests that other factors can facilitate foraging at low light levels.

Haida Gwaii (formerly Queen Charlotte Islands), occurring 80 km off the central coast of British Columbia, have Black Bears but no Brown Bears (Cowan and Guiguet 1956). Molecular phylogenies demonstrate that these Black Bears have high genetic affinity with other coastal subspecies of the Black Bear but are distantly related to interior continental sub-species (Byun et al. 1997). As part of an investi-

gation on trophic associations between Black Bears and salmon on Haida Gwaii, I recorded activity patterns of bears over the salmon spawning period to ascertain the extent of foraging during daylight and darkness. A predominance of daylight activity was predicted based on three lines of evidence, (1) the prevalence of diurnal activity of Black Bears elsewhere in the distribution of the species, (2) the absence of Brown Bears from the archipelago and (3) the low levels of human disturbance in the area.

Study Area

The investigation was carried out at Bag Harbour (52° 22' N, 131° 21' W) in the southern regions of Moresby Island, one of the large islands in the archipelago. From 2000-6000 adult Chum Salmon (*Oncorhynchus keta*) return annually to Bag Harbour from late September to late October. Schools of salmon are most common in shallow waters of the estuary during early October and numbers gradually decline over a three week period as individuals move into the stream. By the last week of October, few individuals remain in the estuary. On capture of a salmon in the stream, bears usually carry the fish into the riparian zone. For 14 days in October 1992 and for 26 days in October 1993, during the major spawning period, I made visual surveys of bear activity on the estuary a minimum of three times during daylight (ca. 0900h,

1200h, 1600h). In 1993, I also made visual surveys of the estuary a minimum of four times during darkness (2100h, 2200h, 0100h, 0400 h) using head-mounted full-face night-viewing goggles (Model AN/PVF5, USA, light amplification 110 000 \times , resolution 270 000 pixels); these provided night-viewing conditions approximately equivalent to mid-day illumination with an overcast sky. During October, sunset (PST) occurs near 1800 h and sunrise occurs near 0700 h; civil twilight extends for 35 minutes both after sunset and before sunrise. Most surveys on the estuary were made from the field camp which was positioned at the forest edge on a small promontory which projected into the estuary. Bears were usually monitored from distances ranging from 5 m to 100 m. Bear surveys in the stream and riparian habitats were made daily throughout study period in both years. I moved quietly so as to minimize any disturbance and increase likelihood of detecting bear. When bears were encountered, I followed them and recorded their activities (2 m to 25 m distance) until they had moved back into the forest after which I continued upstream until another bear was encountered. I made four complete surveys of the stream each day (ca 0930h, 1100h, 1400h, 1700h). I also made daily searches for the fresh uneaten carcass remnants abandoned by bears in the riparian zone.

Results

Throughout the October study period, there was little bear activity on the estuary during daylight although schools of salmon were common in the estuary from late September to October 20. On three occasions in daylight, I saw solitary adult bears moving across the intertidal flats into the forest but even in these instances, no foraging occurred. Greater than 98% of all bear activity on the estuary occurred during darkness. Solitary adults would begin to arrive on the estuary near twilight. With the onset of darkness, numbers of bears gradually increased reaching a maximum (six adults) near 2200 hours following which, numbers declined to zero by dawn (Figure 1). No family groups were observed. All bears foraged during their presence on the estuary but by the last week of October when all salmon had moved into the stream, no more bears were seen on the estuary.

Bears walked slowly into shallow water and waited motionless usually 3 to 10 m from the shoreline. After a short period (<20 minutes), the bear would leap forward and "belly-flop" into the water occasionally capturing a salmon either by pinning the fish to the substrate with the claws or by seizing the fish in the jaws. Over three weeks, I recorded 31 captures in 129 flops (mean 24% success, range 0-100% among days). Salmon were carried back to shore or into the adjacent forest where they were eaten. If no

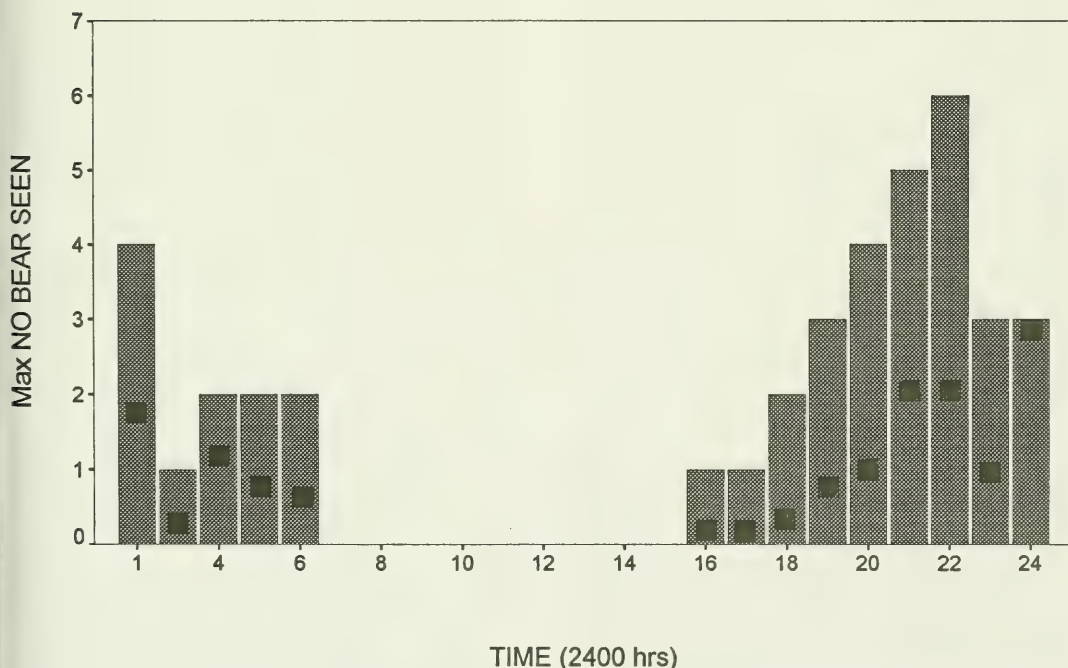


FIGURE 1. Number of Black Bears observed on estuary at Bag Harbour, Moresby Island during chum salmon migration in October, 1993. Data show mean (■) and maximum (histogram) number of bears observed simultaneously during hourly periods. All counts during darkness made with night-viewing goggles.

salmon was captured, the bear repeated the sequence in the same area or moved to another area of the estuary.

Bears distributed themselves throughout a 700 m distance along the shoreline but there was occasional clumping in particular areas where salmon were abundant. On several occasions during darkness, all bears foraged within 50 m along the shore. Despite proximity to each other (ca. 5 m), I saw little evidence for agonistic encounters. In movement along the shoreline, bears usually passed close to each other without conflict. The single aggressive action that I observed during darkness throughout the field season occurred when a bear rushed towards a smaller bear that had just captured a salmon, upon which the latter abandoned its prey, and returned to the tideline to continue foraging.

Within the forested regions of the stream, I made daylight surveys for bear in the riparian zone and in the stream channel. Unlike the pattern on the estuary when bears were rarely seen during daylight, I daily encountered lone adult bears foraging in the stream. Bears searched for salmon under logs and under the overhanging banks. In several pools on the stream where salmon tended to congregate, bears would wade into the pool and seize salmon that swam near the surface and carry these ashore. Spawning activity occurred in shallow water (ca. 10-15 cm) where the salmon were highly visible and partly exposed above the water surface. However, I did not observe bears make any attempts to capture these salmon on the spawning gravels. When the bears walked across the stream, these salmon swam quickly to shelter and were not pursued.

My movement up and down the stream channel was intentionally silent and I typically encountered one or two bears, and on one occasion, four adult bears over the 1 km of spawning gravels. Rarely could I see more than one bear from any single position on the stream as bears were separated from each other by fallen trees as well as by bends in the stream channel. On two occasions that I saw two bears encounter each other on the stream, on first visual contact with the other bear, the smaller of the two ran immediately into the forest beyond the visual range of the larger bear.

I made four surveys of the stream during darkness. While a maximum of one bear occurred on a particular reach (5-10 m) of the stream during daylight throughout the study period, I saw from two to four adult bears foraging in the same reach during darkness. Bears stood in close proximity to each other (<10 m) in the shallow regions where the salmon were spawning. I saw no agonistic encounters among the bears even when salmon were captured. Salmon were eaten on the gravel bars or carried into the for-

est. Replicated early morning and late afternoon transects for carcass remnants in the riparian zone indicate that bears capture the majority (>80%) of salmon during darkness (Reimchen 1994*).

Discussion

Contrary to the original predictions, the majority of foraging activity by Black Bears during the salmon spawning run at Bag Harbour occurred during darkness rather than daylight. Such extensive nocturnal foraging in North American bears has not been previously described. However, since this is the first investigation using night-viewing goggles to monitor nocturnal activity of bears, it is plausible that nocturnal foraging may be common in western North America where bears overlap with migrating salmon.

Crepuscular foraging activity has been reported previously for both Black Bears and Brown Bears. Frame (1974) observed Black Bears foraging near dawn and dusk (0300 - 0600 h, 1600 - 2200 h) on an Alaskan estuary where salmon were congregating. Frame was not able to make systematic counts during full darkness (2200-0300 h) but there was no indication of any reduction in foraging activity during the onset of darkness. The hourly activity pattern is very similar to that observed at Bag Harbour estuary on Haida Gwaii. Olson et al. (*in press*) found increased crepuscular activity of Alaskan Brown Bears foraging on salmon but suggested that this was in response to reduced human disturbance at dusk and dawn, and reflected a less-preferred foraging period. Daylight foraging occurred in an adjacent stream where no human disturbance occurred. However, the habitat with crepuscular foraging activity was much more open than the forested stream where daylight foraging prevailed, similar to the differences between Bag Harbour estuary and stream.

Brown Bears in Alaska also fished during darkness but it was assumed that these were scavenging for dead salmon as visual cues for capturing live salmon would be lacking (Olson et al. *in press*). Machutcheon et al. (*in press*) compared Black Bear daily foraging activity in three disjunct regions of western Canada. On the coastal mainland, where Brown Bears are found, Black Bear activity shifted primarily to darkness while on Vancouver Island, where Brown Bears are absent, Black Bears were mainly active during daylight. Machutcheon et al. (*in press*) concluded that the shift to nocturnal activity of Black Bears on the mainland was in response to Brown Bears, and represented a less-preferred foraging period as capture of salmon would have been more difficult during darkness. However, the bear study on Vancouver Island was not on a salmon river so the comparisons with the mainland are not ecologically equivalent. Brown Bears were equally active during daylight and dark-

*See Documents Cited section.

ness in the salmon season but nocturnal activity was attributed to increased human activity during daylight (Machutchon et al. *in press*).

Increased crepuscular and nocturnal activity of Black Bears on Haida Gwaii can not be due to the Brown Bear as there are no Brown Bears in the archipelago. Furthermore, there are only low levels of human disturbance at this site, particularly during autumn rains when salmon spawning migration occurs, so this is not a likely cause for nocturnal foraging. One cannot exclude the potential competitive effects of indigenous peoples of Haida Gwaii who have inhabited the region for at least 8000 years. However, there has been no permanent use of these estuaries for 80 years (Dalzell 1973). If daylight is a preferred period for foraging, then Black Bears could have been expected to exploit this after 80 years of non-disturbance.

The assumption that darkness equates to lowered foraging success in bears may be reasonable but this is not supported by field evidence. Rather, results from Bag Harbour indicate that crepuscular and nocturnal activities of Black Bears have direct benefits for foraging. In Bag Harbour estuary and stream habitats, bears were visually intolerant to each other during daylight and they spaced themselves outside of the visual field of each other. When two bears came into visual contact with each other, there was immediate evasive responses by one of the individuals. Even in regions of the stream with high salmon density, there was rarely more than a single bear visible during daylight from any single position on the stream. However, during darkness on the same regions of the stream and on the estuary, adult bears frequently foraged very close to each other with only low intensity agonistic responses. The absence of visual cues during darkness appeared to be a major factor in this elevated density of foraging bears.

One additional benefit of nocturnal foraging could be capture efficiency of salmon. Schools of salmon often swam within a few metres of shoreline in the estuary. When I approached during daylight, these schools moved quickly into deeper water and would have been difficult for a wading predator to capture. Yet during darkness, these schools were much less responsive to shoreline intrusion. With night-viewing goggles, I observed salmon moving slowly past bears which were standing motionless in the water (Reimchen 1994*). I was also able to walk slowly into these fish schools without causing serious evasive responses. Capture success of bears appeared to be directly related to number of salmon of the estuary, reaching 100% when fish were abundant in shallow water. Abundance of salmon in the shallow waters was itself associated with activity of Harbour Seal (*Phoca vitulina*) as presence of this predator tended to lead to increased schooling along the shoreline where the seals were unable to swim

(Reimchen 1994*). I did not monitor bear activity on streams during darkness for sufficient periods to ascertain capture efficiency but the overnight accumulation of fresh carcasses in the riparian zone during my early morning surveys and the low accumulation during daylight showed that a large proportion of salmon capture from the stream occurred during darkness.

The specific foraging behaviour of Black Bears during darkness at Bag Harbour was similar to that described for Brown Bears during daylight at McNeill River, Alaska in which the most common fishing technique (during daylight) was the "standing-plunging-forepaws-mouth" sequence (Luque and Stokes 1976). I was unable to determine what stimulus bears used before lunging for salmon during darkness, but it could have been tactile stimuli when salmon swam past the legs of the bears. Another common technique used by Brown Bears in Alaska was the "standing-mouth" sequence in which bears stood motionless, and seized the salmon which were close to the surface. This was also used by Black Bears during daylight in Bag Harbour stream where schools of salmon occurred in small (4 m wide) pools and where fish were restricted in their escape. I did not observe this foraging method on the estuary, probably due to the increased evasive opportunities of salmon.

In summary, data collected from daylight and nocturnal surveys of estuary and stream at Bag Harbour indicates that most foraging on salmon by Black Bears occur during nocturnal periods. Furthermore, various aspects of bear behaviour differ between daylight and darkness including foraging positions, individual distances among bears and levels of agonistic interactions. Neither human nor Brown Bear activities, the main factors contributing to nocturnal foraging on the mainland, are important at Bag Harbour and cannot account for elevated nocturnal activity. Rather, nocturnal activity appears to be a preferred period for foraging, particularly in estuaries where salmon are not spatially restricted. The rapid evasive responses of salmon during daylight to shoreline disturbance and their relative lack of response during darkness, suggest an immediate advantage to nocturnal foraging. Low levels of agonistic responses among the bears during darkness relative to daylight will accentuate the capacity of lower ranking bears to use the high quality habitats during darkness. These trends are consistent with optimal foraging predictions and may have broader geographical relevance because salmon is a major nutrient source for coastal bear populations from Washington, Oregon, British Columbia and Alaska (Gilbert and Lanner 1992; Willson and Halupka 1995). Further nocturnal investigations with night-viewing devices in other geographical areas, and on other ursid species, could be informative for inter-

preting the behavioural ecology of bears during salmon spawning migration.

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Derby-Determined Vital Statistics and Trends of the Smallmouth Bass, *Micropterus dolomieu*, Recreational Fishery in the Middle Reaches of the Grand River, Ontario

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Cooke, Steven J., Christopher M. Bunt, and R. Scott McKinley. 1998. Derby-determined vital statistics and trends of the Smallmouth Bass, *Micropterus dolomieu*, recreational fishery in the middle reaches of the Grand River, Ontario. Canadian Field-Naturalist 112(3): 451-458.

Data from Grand River Bass Derbies (1988-1997) documents trends in relative abundance and provides information on vital statistics of Smallmouth Bass (*Micropterus dolomieu*) in the recreational fishery on the Grand River, Ontario. The length-weight relationship for all fish entered in the derby was described as $\text{weight (g)} = (2 \times 10^5) \times \text{total length (mm)}^{2.95}$. A significant declining trend in mean fish length existed for the 10 longest fish entered in the derby each year over the 10 year period ($r^2 = 0.071$, $p < 0.05$). Relative weights observed were consistently below the length specific standard of 100, similar to other riverine Smallmouth Bass populations. Age and growth rates were similar to other northern riverine Smallmouth Bass populations, and the oldest fish observed was 16 + (441 mm TL). Trends in the middle Grand River Catch Per Unit Effort (CPUE) data suggest that the relative abundance of Smallmouth Bass has decreased significantly since 1988 ($r^2 = 0.552$, $p < 0.05$), although the 10-year derby CPUE (0.36) is similar to CPUE from other riverine populations. The derby data indicates that the population size and structure require further investigations to determine exactly where problems and management opportunities exist.

Key Words: Smallmouth Bass, *Micropterus dolomieu*, relative abundance, Derby data, Grand River, Ontario.

Smallmouth Bass (*Micropterus dolomieu*) are an important game fish in North America (Coble 1975; Scott and Crossman 1973; Edwards et al. 1983). Despite this, very little information exists about the ecology of riverine populations in Canada. One of the most popular riverine Smallmouth Bass fisheries in Canada exists in the middle reaches of the Grand River in southwestern Ontario. This fishery has been poorly studied, largely as a result of its disturbed nature (Mackay 1995) and the difficulties involved in studying fish in large lotic systems (Hendricks et al. 1980; Bunt et al. 1998).

Analysis of tournament fishing results is a relatively inexpensive and simple method for collecting biological data from large rivers (Willis and Hartmann 1986; Ebberts 1987). Rupp (1961) indicated that tournament records based on Catch Per Unit Effort (CPUE) afford valid comparisons of fishing quality because only the efforts of the most skilled anglers are considered. The Grand River Bass Derby is a family event which has been held for 10 years (1988-1997) leading to participation by anglers with a wide range of skills. Although not limited to the most skilled anglers, the Grand River Bass Derby data may still be useful if the general composition of anglers providing data is similar between years. Although competitive angling event data are not appropriate for answering questions relating to population structure, the data may provide the most accurate assessment of fishing quality over long periods of time (Quertermus 1991).

The only data currently available to assess the quality of Smallmouth Bass fishing in the middle reaches of the Grand River are from derby creel cards. Biological data from fish entered in the derby also provide the opportunity to determine the vital statistics of fish.

We report the vital statistics and relative abundance of Smallmouth Bass in the middle Grand River, Ontario, including growth rates, indices of condition, and CPUE determined from data collected at the Grand River Bass Derby 1988-1997. We also describe applications, opportunities and biases associated with the use of derby data. This information will be useful for comparison in investigation of other riverine Smallmouth Bass populations in the northern portion of their range.

Methods

Study Area

The Grand River watershed is located in southern Ontario and covers an area of 6734 km². The Grand River extends 297 km from Dundalk in the north to Port Maitland at Lake Erie. The middle Grand River is an arbitrary title often used to describe the section between West Montrose (43°34' N, 80°26' W) and Parkhill Dam in Cambridge (43°22' N, 80°19' W). Parkhill dam forms a downstream barrier and has no fish passage devices. The Mannheim Weir (43°25' N, 80°25' W), located 17 km upstream from the Parkhill Dam, forms the only other barrier in the study area. The Mannheim Weir has two Denil fishways as

described by Bunt et al. (1998) that pass Smallmouth Bass. Two major tributaries join the Grand River in the study site. Little is known about the fish community in the lower Conestoga River or lower Speed River, although Smallmouth Bass have been documented in both. The topography of the middle Grand River can be characterized by rolling and undulating hills and valleys. Mean daily discharges (1989-1995) at Doon (43°24'N, 80°23'W) were 33.19 m³/s⁻¹ (John Bartlett, Grand River Conservation Authority, unpublished data). Fish community structure, aquatic macrophyte distribution and physical parameters in the middle Grand River are discussed in Coleman (1991). Although the study area is restricted to the middle Grand River, Smallmouth Bass have been documented throughout the Grand River.

Vital Statistics

The Grand River Bass Derby is a family event that has been operated by the Stanley Park Optimists since 1988. The annual two-day event is held during the first weekend in July. After arriving at the weigh-in site in bags or coolers, fish are measured (TL, mm) and weighed (g). Smallmouth Bass are then held in a large aerated cooler for at least five hours prior to being transported and released at common access sites throughout the middle Grand River. Water temperatures during the derby ranged from 18°C to 26°C. Prizes were awarded based on longest total length. Fish entered in the derby were, therefore, not representative of the entire fish population in the middle Grand River. However, they represent the longest smallmouth angled during the two-day event.

Ten years of derby data (1988-1997) containing information on total length (mm) and weight (g) were entered into a database. Condition factors were calculated for each fish using the relative weight (W_r) equation:

$$W_r = (W/W_s) \times 100,$$

where W is the weight of an individual fish (g) and W_s is a length-specific standard weight.

The form of the W_s equation is

$$\log_{10}(W_s) = a' + b \times \log_{10}(L),$$

where a' is the intercept value and b is the slope of the $\log_{10}(\text{weight})$ - $\log_{10}(\text{length})$ regression equation and L is the maximum total length of the fish.

The RLP technique provided the following 75th percentile W_s equation (Kolander et al. 1993) for fish 150 mm and longer:

$$\log_{10} W_s = -5.329 + 3.200 \log_{10} L.$$

A length-weight regression was generated for all fish entered in the derby using a quadratic model.

The 10 largest individuals in total length for each year were extracted from the database. Because some anglers entered fish in the derby which were small (i.e., less than 400 mm TL), it was not possible to make comparisons of mean length for all fish entered. By using only the 10 longest individual fish from each year, we were assured that they are useful in documenting trends in mean length of the fish entered in the derby each year.

A model one fixed-effect, one way ANOVA was used to test the null hypothesis of no differences among means for length of the 10 longest individuals among each of the 10 years. When means are tested for pairwise differences the probability of finding one significant difference by chance alone increases rapidly with the number of pairs, so the Tukey-Kraemer HSD test was used, as recommended by Day and Quinn (1989). All tests were calculated using SYSTAT V. Linear regression analysis was used to determine if relationships existed between variables. A loess plot (smoothing parameter 0.5) was used to determine if there was an overall linear trend prior to fitting a line. All tests were performed using an alpha level of 0.05.

In 1996, scales were taken laterally from just posterior to the relaxed pectoral fin ($n = 61$). Scales were cleaned and random scales for each fish were displayed on a microprojector to determine annuli (Reynolds 1965; Robbins and MacCrimmon 1977). A card strip was laid along the nucleus midpoint and the anterior median scale margin and each annulus and the scale margin was marked (Bagenal and Tesch 1978).

Since annulus formation occurred almost simultaneously with the timing of the derby (i.e., late June), ages were interpreted as being one year greater than the number of annuli unless the new annulus had just formed (Beckman 1942; Robbins and MacCrimmon 1977). Mean lengths of the various year classes were determined by back-calculation using scale annuli (Everhart 1950). Length-at-age up to the time of capture was estimated with the Fraser-Lee rectilinear body-scale regression method developed by Carlander (1982) using DisBCal89 (Missouri Department of Conservation, Version 1989). We assumed that the length of fish before scale formation was 35 mm, thereby ensuring that the intercept (a) in the rectilinear body-scale regression was constant, as used by Weathers and Bain (1992).

Relative Abundance

Creel cards were distributed and collected at the Grand River Bass Derby as draw prizes to encourage cooperation with the provision of CPUE data. Every angler in the derby received a card which asked basic questions including duration of angling, location and catch. CPUE for derby participants is calculated for each year. Linear regression analysis was used to examine the relationship between derby

CPUE and the year of the derby. Responses to the number of days spent angling in the Grand River over the period of a year were used to assess the abilities of anglers. This served as a standardized measure of sampling efficiency and the relationship was examined using linear regression analysis.

Results

Vital Statistics

In total, 514 Smallmouth Bass were entered in the Grand River Bass Derby from 1988 to 1997. The length-weight regression for all fish entered in the derby over 10 years (Figure 1) can be described as weight (g) = $(2 \times 10^5) \times \text{total length (mm)}^{2.95}$. The largest fish (531 mm TL) was entered in the derby in 1988.

There was a trend toward decreasing sizes of fish being caught. The mean lengths for the 10 longest fish in each of the derby years (1988-1997) differed significantly (ANOVA $F = 3.507$, $p = 0.001$) among years. Mean lengths from 1996 were significantly lower (Tukey-Kramer HSD) than mean lengths of fish from 1989 ($p = 0.010$) and 1992 ($p = 0.003$), lengths from 1995 were less than those from 1992 ($p = 0.032$) and fish caught during 1997 were smaller than those caught in 1992 ($p = 0.024$). The mean lengths of fish did not differ significantly among

other years ($p > 0.05$). The regression (Figure 2) was negatively correlated ($r^2 = 0.071$) and highly significant ($F = 7.441$, $p = 0.008$).

Relative weights for all fish entered in the derby from 1988 to 1997 were low (Figure 3). Less than 5% of the W_r values were greater than the length specific standard of 100. The regression was negatively correlated ($r^2 = 0.071$), highly significant ($F = 39.018$, $p < 0.001$), and declined with increases in fish length.

The oldest Smallmouth Bass entered in the Grand River Bass Derby was 16 years of age. Due to scale degeneration, the first annulus was difficult to identify in almost all samples, resulting in the provision of growth information for age classes 2 and older (Table 1). Most of the fish entered in the derby were between 7 and 14 years old. Growth was most rapid during the first 6 years. After attaining ages greater than 6 years, growth rates declined as evidenced by reduced average annual growth increments.

Relative Abundance

Between 1988 and 1997, 3314 creel cards were submitted, reflecting 37 553.85 hours of effort and 13678 Smallmouth Bass angled. The total derby CPUE over the 10-year period was 0.364 Smallmouth Bass per hour. The highest CPUEs were reported in the first two years of the derby (Table 2).

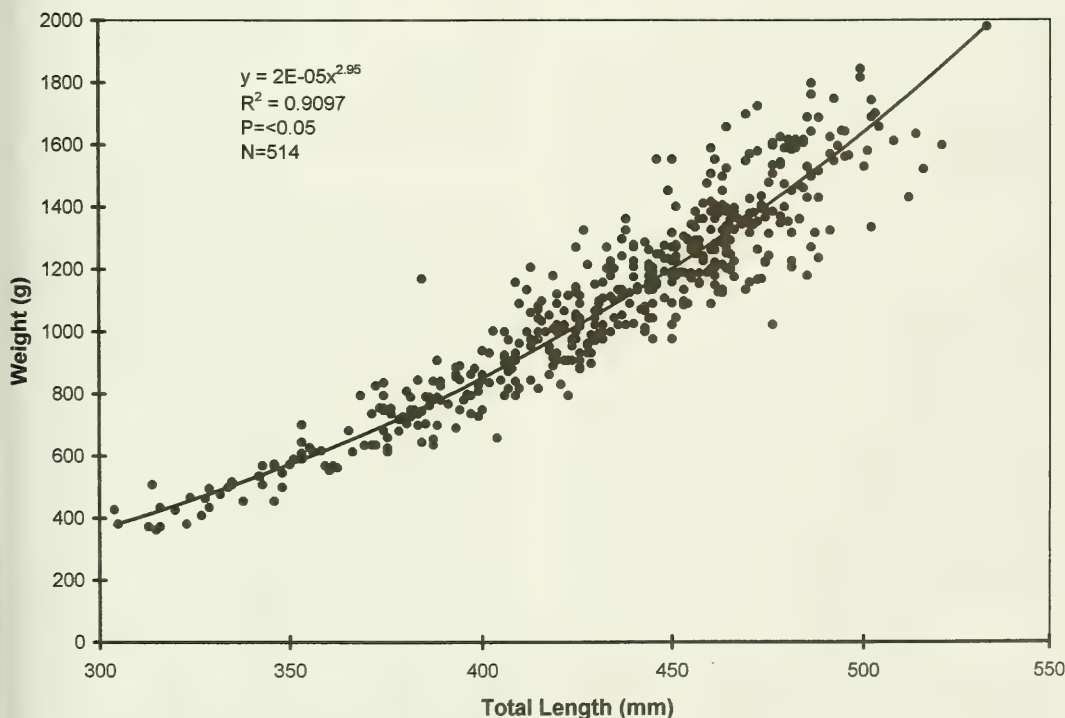


FIGURE 1. Length-weight regression for Smallmouth Bass entered in the Grand River Bass Derby from 1988 to 1997. The relationship is defined as weight (g) = $(2 \times 10^5) \times \text{total length (mm)}^{2.9464}$.

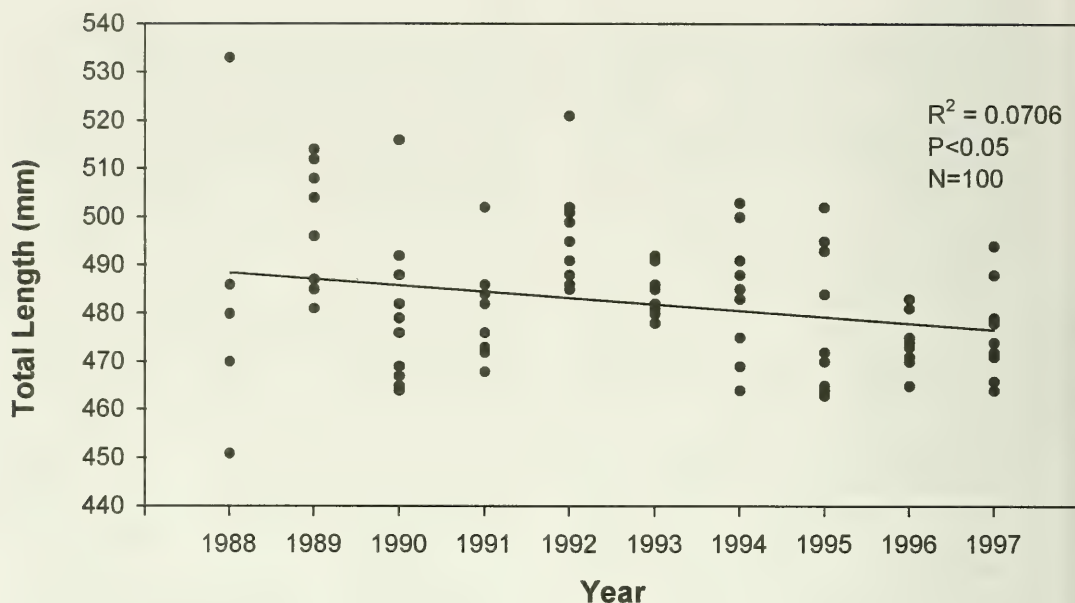


FIGURE 2. The ten longest (TL, mm) Smallmouth Bass entered in the Grand River Bass Derby each year (1988-1997).

The lowest CPUEs were observed in 1991, 1994, 1996, and 1997.

The relationship between derby CPUE and time (Figure 4) was negatively correlated ($r^2 = 0.552$) and significant over the 10-year period ($F = 9.876$, $p = 0.014$). There appeared to be no difference in the expertise of anglers because the mean number of days spent angling the Grand River by derby participants was similar between years. There was no significant relationship between mean number of days fished on the Grand River and CPUE ($F = 0.673$, $p = 0.436$).

Discussion

Difficulties arise when attempting to obtain an unbiased sample of any population under study (Pope and Willis 1996). Angling, like most sampling methods, is size selective, usually towards the faster-growing segment of a given year-class (Miranda et al. 1987). Miranda et al. (1987) reported that fish collected by anglers misrepresented the growth rate of a population, especially at younger ages. Such biases in growth estimates derived from fish collected by anglers can be eliminated if year-classes that are not fully recruited into the fishery are excluded from analysis, as we did here. This was an intrinsic property of the derby method of fish collection since that anglers only entered fish that were potentially large enough to qualify for prizes.

Additional biases exist with regards to individual variation in catchability (Martin 1958; Burkett et al. 1986). However, this is still poorly understood for Smallmouth Bass and deserves further attention.

Nonrandom sampling of the stock probably selected larger and more aggressive members of younger ages-classes (Bagenal and Tesch 1978). This is an inherent bias when analyzing data from angler-caught fish (Miranda et al. 1987). For these reasons, the information presented here can be used only for relative comparisons and for documenting trends through time.

The low relative weights observed from the Grand River derby fish are consistent with many other riverine populations. Weiss-Glanz and Stanley (1984) reported that almost all relative weight values in the Penobscot River, Maine, were below 100 and that the variation in relative weight increased with fish size. The low relative weights suggest slow growth, but could also indicate that riverine Smallmouth Bass are slimmer than those dwelling in lakes (Weiss-Glanz and Stanley 1984). For this reason, a standard weight equation for both lentic and lotic populations of Smallmouth Bass should be generated.

The standard weight equation we used (Kolander et al. 1993) was derived from 50 data-sets representing 6731 fish. Although attempts were made to obtain Canadian data-sets, none were submitted. Smallmouth Bass in the northern part of their range may also exhibit reduced growth due to the shorter growing season. However, Kolander et al. (1993) found no geographic pattern in relative weight values for Smallmouth Bass, as had been previously noted for Yellow Perch, *Perca flavescens* (Willis et al. 1991).

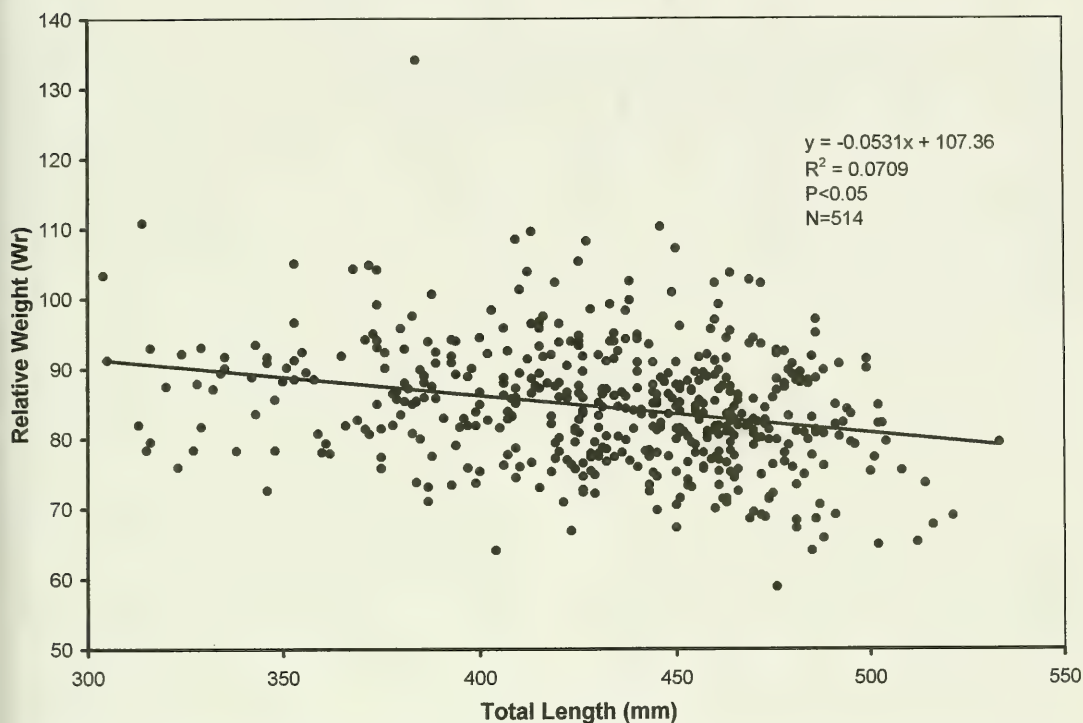


FIGURE 3. Relationship between relative weight (W_r) and total length (mm) for all Smallmouth Bass entered in the Grand River Bass Derby (1988-1997).

Because of the potential variability of relative weight as a function of season and size of fish, it is not a particularly accurate predictor of growth rate (Anderson and Neuman 1996). However, low values,

such as those found in the present study, may indicate both problems and management opportunities. Variability in condition factor was minimized by consistently sampling fish on the same weekend every year. However, if fish were caught prior to spawning, the relative weight values would be inflated. This is one of the major problems when biologists investigate relative weight since the standard weight equations are not time specific and disregard gonadal condition.

Caution must be used when interpreting age and growth results presented here due to the biases associated with the sampling method and the difficulties involved with the accurate aging of scale samples from old Smallmouth Bass. Robbins and MacCrimmon (1977) validated the scale method for aging Smallmouth Bass by removing and sectioning the pelvic spine. They reported that age estimates based upon scale and finray methods were in agreement. The removal of scales from fish entered in the Grand River Bass Derby is a quick and relatively non-invasive technique for obtaining age and growth data. The removal of otoliths was precluded by our reluctance to sacrifice large individuals among the population of angler-caught fish.

Smallmouth Bass achieved a maximum observed age of 16 years in the Grand River. Previously reported maximum ages for Smallmouth Bass are generally 15 years, and most have been from lacustrine popula-

TABLE 1. Average back-calculated total lengths (mm) for each age class from Grand River Smallmouth Bass. Standard errors are presented below each calculated length. Scales were collected from 61 fish during the 1996 Grand River Derby.

Back calculation age	All classes (mean TL mm)	SEM	N
2	182.87	3.659	61
3	226.96	4.099	61
4	267.40	4.313	61
5	302.04	4.579	61
6	329.71	4.427	60
7	352.75	4.557	56
8	375.53	4.379	50
9	393.45	4.727	43
10	406.86	5.006	36
11	416.83	5.175	30
12	423.62	5.570	21
13	436.28	6.323	13
14	436.13	5.865	8
15	442.05	13.289	3
16	441.38	0	1

TABLE 2. Summary information derived from 3314 Grand River Bass Derby creel cards submitted from 1988-1997.

Year	Total number creel cards submitted	Total number of bass caught	Derby CPUE (bass/hour)	Mean number of days angler per year*
1988	238	1061	0.480	16.0
1989	237	2108	0.785	18.3
1990	440	1856	0.403	15.3
1991	523	1446	0.298	18.6
1992	410	2052	0.416	19.6
1993	423	1805	0.358	16.7
1994	320	915	0.246	18.3
1995	247	1007	0.313	13.3
1996	247	711	0.207	16.9
1997	229	717	0.250	12.5

*By Derby participants on the Grand River.

tions in Ontario (Stone et al. 1954; Scott and Crossman 1973). Carlander (1977) reported that the maximum life span of Smallmouth Bass is about 18 years. Riverine populations in Ontario or other northern parts of their range have not been studied extensively. Growth of Smallmouth Bass entered in the Grand River Bass Derby is slower than other riverine fish populations (Coble 1967; Carlander 1977).

The growth season in Ontario is limited by short periods of warm water, generally resulting in small average annual growth increments (Carlander 1977). Variable growth rates have also been attributed to differences in food supply (Coble 1975). The Grand River has many species of forage fish, as well as crayfish, which likely comprise the majority of the food consumed. In a fluvial system, fish must often expend energy to maintain position in the flow or to

accomplish upstream migrations. Such energy expenditures are reduced in lentic populations, resulting in increased opportunities for growth. Heavy parasite burdens may also restrict growth of Smallmouth Bass (Hunter and Hunter 1938). Cestodes were common in the digestive tracts of Smallmouth Bass from the middle Grand River.

CPUE determined from derby data is an effective measure of fishing quality and relative abundance (Quertermus 1991). The CPUE for Smallmouth Bass in rivers and streams without harvest regulations across North America is highly variable (Weathers and Bain 1992), and CPUE data from the middle Grand River is similar to the median from other data sets. Trends in the middle Grand River CUE data suggest that the relative abundance of Smallmouth Bass has decreased since the derby's inception.

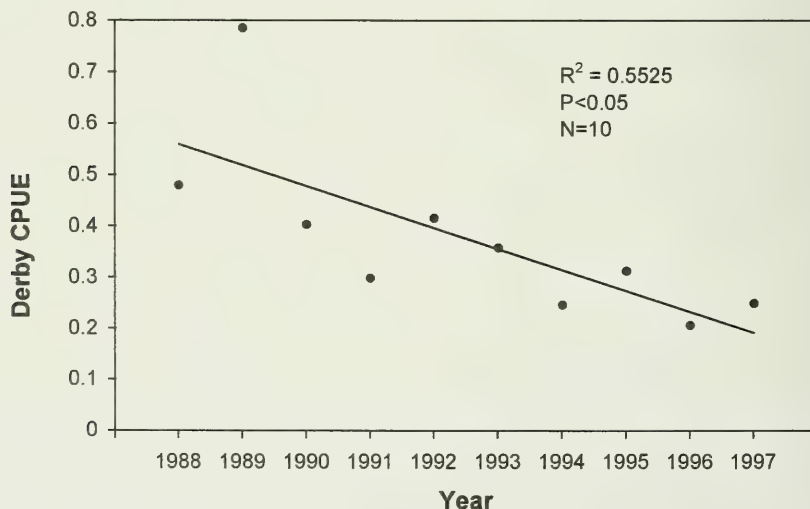


FIGURE 4. CPUE for anglers who targeted Smallmouth Bass during the Grand River Bass Derby (1988-1997). Data were derived from creel cards submitted by participating anglers.

Concerns have been raised about increased pressure, over-harvest, habitat degradation and the impacts of the Grand River Bass derby. Access to the river has improved and several companies offer canoe rentals that previously were not present, enabling more anglers to reach areas which previously received little fishing pressure. The derby has also provided increased exposure for the Smallmouth Bass fishery, perhaps stimulating further interest in angling for Smallmouth Bass in the middle Grand River.

Since no estimates of population size or structure exist from the middle Grand River, the use of derby data to document changes in relative abundance of Smallmouth Bass becomes a viable alternative. The Grand River Bass derby was repeated annually and attracted participants with similar angling patterns. This standardized format provided an opportunity to document trends in the vital statistics and relative abundance of the Smallmouth Bass fishery of the middle reaches of the Grand River. However, angler provided data is only useful if all potential biases are identified, and if possible, controlled.

Collection of meristic information from individual fish and CPUE data provides an opportunity for anglers to participate in key aspects of fisheries assessment and management. When anglers feel that they are contributing to the protection and enhancement of the resource, the opportunity to obtain accurate and complete data increases (Pollock et al. 1994).

The Grand River Bass Derby data indicated that the population size and structure require further investigations to determine exactly where problems and management opportunities exist. Electrofishing surveys would complement the angler-provided data by providing information on population structure and biomass. Similar to Quertermus (1991) we agree that derby data cannot be used to assess population structure and are, therefore, insufficient to serve as the sole source of data to determine management opportunities.

Acknowledgments

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Feeding Ecology of Juvenile Lake Sturgeon, *Acipenser fulvescens*, in Northern Ontario

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Beamish, F. William H., David, L. G. Noakes, and Andrew Rossiter. 1998. Feeding ecology of juvenile Lake Sturgeon, *Acipenser fulvescens*, in northern Ontario. Canadian Field-Naturalist 112(3): 459–468.

Dietary analyses of juvenile Lake Sturgeon in a resource-poor habitat showed them to be a general predator. Cladocera dominated numerically the prey taxa, but were recorded in only four of the individual sturgeon examined and therefore excluded from stomach content analyses. Mayfly larvae (Ephemeroptera), primarily *Hexagenia*, were numerically the next most abundant (34% of all prey items) and the most widely taken (75% of all sturgeon) of the 10 prey categories. Others were Odonata, Annelida, Mollusca, Diptera and Trichoptera, each at 5–8% of all prey items. The remaining dietary categories represented < 3% of all prey items. No dietary partitioning was found over the length range of juvenile sturgeon, suggesting that fish throughout this size range are almost certainly competing for food. Lake Sturgeon diet did not differ from that for suckers, Lake Whitefish and, to some extent, Burbot, but was different from that for Northern Pike and Walleye. Extremely low invertebrate densities (95 individuals \times m⁻²) and occurrence of all benthic species in the diet of juvenile Lake Sturgeon and several of the other dominant fishes suggests niche breadth to be wide and thus competition for food to be severe. The low food abundance is reflected in the comparatively slow growth rate of sturgeon in our study area. Apparently sturgeon are at survival threshold in this area. Further depletion of their food base likely would have serious repercussions for their growth and survival.

Key Words: Lake Sturgeon, *Acipenser fulvescens*, Lake Whitefish, *Coregonus clupeaformis*, Longnose Sucker, *Catostomus catostomus*, Northern Pike, *Esox lucius*, Walleye, *Stizostedion vitreum*, White Sucker, *Catostomus commersoni*, diet, ecology, macrobenthos, Ontario.

The native range of Lake Sturgeon, *Acipenser fulvescens*, included the drainage basins of the Mississippi River, the Laurentian Great Lakes and Hudson Bay (Harkness and Dymond 1961; Scott and Crossman 1973). A variety of anthropogenic factors have resulted in the severe decline or extirpation of populations across much of its former range. With fishing restricted or banned in most places, the principal threats to Lake Sturgeon populations now come from habitat degradation.

Empirical studies, and ecological theory, point to the importance of habitat and food as the two major axes of resource partitioning (Schoener 1983; Ross 1986). Individuals within a population usually display differences, often subtle, in their utilization of a limiting resource. This is often expressed in ontogenetic shifts in habitat occupied or foods taken. If such shifts do not occur, asymmetric intraspecific competition can result (e.g., Persson 1983).

The present study was undertaken as part of a larger project investigating the biology of Lake Sturgeon in the Moose River Basin, Ontario, Canada. Our extensive sampling revealed Lake Sturgeon of a wide range of sizes and ages within the same study area and raises questions as to their feeding ecology. To determine the food base available we examined the composition and abundance of benthic macro inverte-

brates. We also examined the composition of stomach contents of sturgeon over a range of lengths (25–80 cm fork length) and ages (2–17 years). Since Lake Sturgeon in our study area mature at > 19 years for males and > 22 years for females (Nowak and Jessop 1987), our study involved juveniles. We identified food partitioning by comparing stomach contents to the abundance of benthic prey organisms to define food electivity (Ivlev 1961) and food overlap (Pianka 1973) values among length classes of sturgeon. This analysis of dietary breadth is also important to define habitat suitability for sturgeon, and to predict the likely impacts of habitat disruption on both benthic prey and sturgeon.

Materials and Methods

Our field sampling was conducted mostly during summer (June–August) of 1990–1992 in a portion of the Groundhog and Mattagami rivers (49°45'N, 81°54'E) within the Moose River basin of northern Ontario, Canada. A small sample of Lake Sturgeon was also collected in late March, 1992. The study area extended from Cypress Falls on the Mattagami River to several kilometres downstream from its confluence with the Groundhog River, and a stretch of the Groundhog River extending approximately 6 km upstream of the confluence.

Sturgeon were captured in gill nets, bottom set at selected locations within the study area for 8–12 h twice daily. The entire study area was divided into 20 sections each of approximately 2 km river length. The locations of nets were designated on the right or left river bank at 200 m intervals within each section. Each net location was given an unique code number to identify river section, right or left bank and position within each section. Net locations were chosen by code numbers, without replacement, so that by the end of each field season each net location had been sampled once. To reduce net selectivity we used gangs of experimental monofilament gill nets of various mesh sizes (2.5–12.7 cm stretched mesh). Nets were 2 m high, and the total length of each net gang was approximately 120 m.

For reasons of conservation, stomach contents were examined for only a few of the sturgeon captured. Non-lethal attempts to determine sturgeon diet by flushing stomachs (Meehan and Miller 1978) were unsuccessful. We therefore examined stomach contents from sturgeon some of which were killed for bioenergetic studies ($n = 34$, Beamish et al. 1996), were found dead in nets ($n = 22$), or killed specifically to examine their stomach contents ($n = 28$). Sturgeon were measured for fork length (FL; ± 1 mm), weighed to the nearest 10 g and their stomachs removed. The stomach was opened by a longitudinal incision and volume of contents was estimated after which they were gently flushed with water into a sorting tray. Volume of stomach contents was estimated by comparison with models of known volume and varied by less than 10% of actual.

Prey items were enumerated for 84 stomachs, 75 from June–August and from a single sample of nine in late March. The time between a sturgeon's capture in a gill net and removal of its stomach contents could have varied from < 1 to approximately 12 hours. Some digestion must have taken place while sturgeon were in the nets but digestion rates are unknown for Lake Sturgeon (Mason and Clugston 1993). Regurgitation of food is a further source of potential error (Bowen 1983), but again there are no estimates of this.

Intraspecific food partitioning can be subtle, and considering food organisms in categories that are too broad may hide selection patterns (Moore and Moore 1976a). Therefore we initially identified all organisms to genus or species where possible. We analyzed ontogenetic differences in feeding habits by comparing diet over the length range of juvenile sturgeon examined. We grouped fish by 10 cm FL intervals. Each interval contained approximately three year-classes of sturgeon. The relative importance of each prey category was expressed by its numerical importance and frequency of occurrence (Cortés and Gruber 1990; Cortés 1997). Numerical importance was calculated for each fish as the number of individuals within each prey category relative

to the total number of prey recovered from a stomach, expressed as a percentage. This procedure was adopted to reduce the bias favouring small prey items across all sturgeon within a size category. Frequency of occurrence was calculated as the number of sturgeon containing a particular prey in their stomachs relative to the number of fish with food in their stomachs, regardless of taxa. The prey category with the highest numerical importance and frequency of occurrence was considered as the "main" food (Berg 1979). Numerical importance values were used also to calculate overlap indices (Pianka 1973). Overlap index values can vary between 0 and 1, with 0 indicating complete dietary segregation and 1, complete overlap between component length classes. Overlap values are considered arbitrarily high (> 0.6), intermediate ($0.4 - 0.6$) or low (< 0.4) (Grossman 1986; Ross 1986).

In addition to Lake Sturgeon, Longnose Suckers, *Catostomus catostomus*, White Suckers, *C. commersoni*, Northern Pike, *Esox lucius*, Lake Whitefish, *Coregonus clupeaformis*, Burbot, *Lota lota*, Walleye, *Stizostedion vitreum*, and Yellow Perch, *Perca flavescens* were also captured in the gill nets. Stomach contents were examined for a sample of all species except Yellow Perch using the same prey categories described for Lake Sturgeon with one additional category, fish. Fish to be examined were captured in gill nets set during June–August, 1991; fork length and mass were measured to the nearest 1 mm and 10 g, respectively, and the stomach removed, opened and the contents flushed as described for Lake Sturgeon. Total length was measured for Burbot as they are without a forked tail. Contents of the entire digestive tract of White and Longnose suckers were examined as these species lack an identifiable stomach. Importance of each prey category was expressed for each fish species by its numerical importance and frequency of occurrence, calculated as described above. Dietary comparisons among fish species were made on the basis of overlap index values and Spearman's rank order correlation using non parametric statistics (Steel and Torrie 1980; SAS Institute Inc. 1988).

Collection and examination of macrobenthos

We estimated prey abundance by taking samples of benthos from the substrate with an Ekman dredge (15×15 cm). An initial cursory comparison between Ekman and Ponar dredges of similar size did not indicate a difference in the benthic taxa captured nor in their abundance. We collected benthos in each of 1990, 1991 and 1992, but our most extensive sampling was in 1991 when 500 samples were collected. Ten samples were taken at approximately equal intervals along each of ten transects approximately 700 m apart within each of five river sections. Each river section was about 7 km in length and the five sections collectively covered the entire

TABLE 1. Mean (\pm SD) density, range, numeric importance and frequency of occurrence of invertebrates based on 572 samples within the macrobenthos community of the Mattagami and Groundhog Rivers, June – August, 1990 – 1992. Details of sampling are given in the text.

Category	Individuals \times m ⁻²			Numerical Importance %	Frequency of Occurrence %
	Mean	SD	Range		
Diptera	32.9	123.5	0-1866	26.8	48.7
Ephemeroptera	29.1	28.3	0-711	34.4	57.9
Annelida	11.0	51.3	0-704	11.1	18.9
Trichoptera	10.2	50.2	0-755	10.6	22.8
Mollusca	7.5	40.6	0-800	10.5	18.9
Odonata	2.1	22.1	0-44	2.6	7.0
Megaloptera	1.2	7.9	0-88	1.8	5.8
Plecoptera	0.2	2.3	0-44	0.2	0.8
Decapoda	0.1	2.0	0-44	<0.1	0.4
Other	1.1	7.5	0-44	2.2	5.0

study area. In 1990 and 1992 smaller numbers of samples were collected throughout the study area. The contents of each Ekman grab were individually bagged and preserved in 10% formalin for later examination.

We separated invertebrates from substrate material by flotation in a saturated sucrose solution, followed by manual sorting of remaining material. Examination of samples which had undergone these procedures showed that this method removed more than 95% of all invertebrate materials present.

Calculation of prey preference

Prey preference was determined by comparing prey abundance and dietary constituents by means of an electivity index (E; Ivlev 1961):

$$E = (r_i - p_i) / (r_i + p_i)$$

where r_i is the percentage frequency of a given prey category in a stomach and p_i , the percentage frequency of that prey category in the benthos. Electivity values may range from +1 (prey in a

stomach but not in the benthos) to -1 (prey in the benthos but not in a stomach). A value of 0 indicates neither selection nor rejection of that prey group by sturgeon.

Results

A total of 6979 fish of all species were captured in 540 gill net sets. Relative numerical abundance was greatest for Walleye (36.9%) and White Sucker (21.1%). Lake Sturgeon and Longnose Sucker were of intermediate relative abundance at 16.5 and 14.2%, respectively. Captures of Northern Pike (4.2%), Lake Whitefish (3.1%), Yellow Perch (3.0%) and Burbot (1.1%) were much less frequent.

Macrobenthos and prey composition

Forty-one genera representing three phyla and 27 families were identified among the invertebrates recovered from the benthic samples. Benthic organisms were most abundant in substrate dominated by sand and clay (Chiasson et al. 1997). An appreciable portion of the river bed was strewn with wood chips

TABLE 2. Mean number (\pm SD) of individuals within each dietary category found in the stomachs of Lake Sturgeon during June – August, 1990 – 1992. Details of calculation for numerical importance and frequency of occurrence are given in the text.

Category	Number of Individuals per Lake Sturgeon			Numerical Importance %	Frequency of Occurrence %
	Mean	SD	Range		
Diptera	8.4	32.0	0-258	5.8	50.7
Ephemeroptera	115.6	186.5	0-900	65.8	74.7
Annelida	1.8	3.8	0-18	6.7	33.3
Trichoptera	5.2	19.1	0-78	5.1	30.7
Mollusca	1.5	7.6	0-56	5.1	10.7
Odonata	2.0	5.4	0-30	7.7	37.3
Megaloptera	0.3	0.8	0-4	0.5	13.3
Plecoptera	0.1	0.5	0-3	0.5	6.7
Decapoda	0.2	0.6	0-3	2.8	18.7
Other	0.1	0.4	0-2	0.1	3.8

Table 3. Dietary overlap values among length classes of juvenile Lake Sturgeon. Values can vary between 1 and 0 with values greater than 0.6 indicative of significant dietary overlap between the component pair. Details of calculations are given in the text. Sample size is given in brackets.

Sturgeon fork length cm	30-39.9 cm (11)	40-49.9 cm (16)	50-59.9 cm (14)	60-69.9 cm (26)
40 - 49.9	0.992			
50 - 59.9	0.979	0.980		
60 - 69.9	0.990	0.990	0.982	
> 70 (5)	0.990	0.999	0.973	0.998

and was particularly depauperate of macrobenthos. Overall, the relative density of benthic fauna was low with a mean (\pm SD) of 95.4 (\pm 232.4) individuals \times m⁻² (Table 1).

Many of the genera of benthic fauna were scarce and comprised < 1% of the total number of invertebrates recovered. Indeed, several taxa were recorded only as single individuals. Taxa were therefore assigned to one of nine "principal prey" groups, dietary categories whose component taxa were present in stomachs of \geq 5% of all sturgeon examined (Martell and McClelland 1994). Those few dietary items which could not be identified or were rarely found were placed in a tenth category called "other". Although principal prey represent only a small portion of all species consumed, they are the source of most variance observed in diets (Tyler 1972; Green 1979; Hacunda 1981).

Among the macrobenthos groups, Diptera and Ephemeroptera were numerically dominant constituting 32.9 and 29.1 individuals \times m⁻² (Table 1). Numeric importance and frequency of occurrence were each slightly larger for Ephemeroptera than Diptera. Within the Diptera, *Ablabesymia*, *Tanytarsus*, *Polypedilum* and *Chaoborus* were most abundant. Also present but in lower abundance were representatives of the genera, *Bezzia*, *Procladius*, *Prodiamesa*, and *Tipula*. Within the Ephemeroptera,

members of the genus *Hexagenia* were by far the most abundant representing almost 92% of the individuals captured. Other Ephemeroptera genera represented were *Caenis*, *Ephemerella*, *Paraleptophlebia* and *Stenonema*. Annelida and Trichoptera were of similar numerical importance in the macrobenthos community but were both much less abundant than the dipterans or ephemeropterans (Table 1). Annelids were almost entirely from the class Oligochaeta and genera, *Stylodrilus*, *Limnodrilus* and *Tubifex*. The few remaining annelids were from the class Hirudinea and genera, *Placobdella*, *Helobdella* and *Nepheleopsis*. Among the trichopterans, cased caddis comprised 70% of the group with net-spinning caddis contributing the remaining 30%. Individuals of the genera *Neophylax* and *Oecoetis* of the cased caddis were dominant, while the net-spinning caddis were mainly represented by two polycentropodids, *Polycentropus* sp. and *Neuroclipsis crepuscularis*.

Molluscs were represented in the macrobenthos by the gastropods, *Gyraulus*, *Physella* and *Amnicola*, and the bivalves, *Pisidium*, *Unio*, *Sphaerium* and *Musculium*. Odonata were mostly from three genera, *Aeshna*, *Dromogomphus* and *Gomphus* with occasional individuals from three other genera, *Macromia*, *Octogomphus* and *Ophiogomphus*. All megalopterans and plecopterans were each of one

TABLE 4. Electivity indices for length classes of juvenile Lake Sturgeon in relation to each dietary category. Values can vary from -1 to +1. Negative values indicate avoidance of or inefficient foraging on that prey category. A value of 0 indicates neither selection nor rejection. Sample size is given in brackets.

Prey Category	30-39.9 cm (11)	40-49.9 cm (16)	50-59.9 cm (14)	60-69.9 cm (29)	> 70 cm (5)	Total Population (75)
Diptera	-0.81	-0.85	-0.35	-0.80	0	-0.71
Ephemeroptera	+0.43	+0.50	+0.40	+0.49	+0.51	+0.44
Annelida	-0.24	-0.83	-0.74	-0.97	0	-0.81
Trichoptera	-0.14	-0.84	-0.55	-0.66	0	-0.64
Mollusca	0	0	-0.82	-0.56	0	-0.77
Odonata	+0.09	-0.08	+0.19	-0.83	+0.24	-0.17
Megaloptera	-0.28	-0.85	-0.72	-0.85	0	-0.75
Plecoptera	-0.02	-0.36	-0.36	-0.36	0	-0.26
Decapoda	+0.67	-0.33	+0.50	0	0	-0.38

Table 5. Dietary overlap values among the major species of fish in the Mattagami and Groundhog Rivers. Values can vary between 1 and 0 with values greater than 0.6 indicative of significant dietary overlap between the component pair. Details of calculations are given in the text. Sample size is given in brackets. Length in centimetres and mass in grams.

	Length ±SD	Mass ±SD	Walleye	Suckers	Lake Whitefish	Northern Pike	Burbot
Lake Sturgeon (75)	53.7 ± 12.6	1306 ± 841	0.508	0.517	0.688	0.022	0.755
Walleye (40)	34.6 ± 7.4	569 ± 513	—	—	—	—	—
Suckers (13)	39.6 ± 5.5	885 ± 354	0.346				
Lake Whitefish (10)	43.2 ± 9.9	1654 ± 637	0.370	0.909			
Northern Pike (30)	47.3 ± 9.1	868 ± 712	0.866	0.092	0.001	—	—
Burbot (16)	30.5 ± 9.5	280 ± 269	0.630	0.742	0.872	0.285	—

genus, *Sialis* and *Acroneuria*, respectively, and all decapods were of a single species, *Oronectes propinquus*.

Diet of Lake Sturgeon

We found food in the stomachs of 66 (88%) of the 75 fish examined between June and August. Lake Sturgeon ate a wide variety of prey (Table 2). Most fish had one to four of the 10 prey categories in their stomachs, the average being three and there was great inter-individual variation in diet (Table 2).

All macro invertebrate taxa recorded in the benthic samples were also found in Lake Sturgeon stomachs. However, one prey category, Ephemeroptera, notably the genus *Hexagenia*, was regularly of numerical importance for juvenile Lake Sturgeon of all lengths. *Cladocera* were recorded in only four individual sturgeon each of which was in a different size group. The extremely high numbers of *Cladocera* consumed by these individuals (up to 8700 individuals) meant that in three of the size groups they were numerically the most dominant food item, comprising 39.5–83.5% of the overall diet of that size group. However, numerical estimates overemphasize the importance of small prey organisms taken in large numbers (Crisp et al. 1978; Hyslop 1980), and these large numbers of individually small *Cladocera* comprised a relatively small total biomass. Additionally, the Ekman dredge we used for benthic sampling would have grossly underestimated the diurnal density and abundance of cladocerans, and thereby severely biased our availability and electivity estimates. We therefore excluded this group from further analyses of stomach contents and food electivity.

When *Cladocera* were excluded the dietary component with the highest prey value was Ephemeroptera, primarily the burrowing mayfly

Hexagenia which consisted of a single species, *H. limbata*. Most (74.7%) of the sturgeon with food in their stomach contained this prey (Table 2). Dipteran larvae had a frequency of occurrence of almost 51% and were the second most important dietary component on the basis of number of individuals found in stomachs. In terms of relative numerical importance, the Dipterans were over an order of magnitude lower than the Ephemeroptera and only slightly less than Odonata nymphs. However, the actual number per sturgeon and numerical importance were low compared to Ephemeroptera (Table 2). Tricoptera were also of intermediate importance to the diet of juvenile Lake Sturgeon. Other prey were relatively scarce. Annelida were numerically few, and consisted primarily of tubificid and lumbriculid worms. Some sturgeon contained gastropods, usually in low numbers, although one individual had 56 in its stomach.

Volume of food in Lake Sturgeon stomachs captured between June and August varied inversely with fork length. The relationship is described by the regression:

$$S_c = 1.617 - 0.023 L_f \text{ (n = 71, r = 0.560; P < 0.05)}$$

where S_c is the volume of stomach contents (ml) expressed as a percentage of body mass (g; %BM)) and L_f is sturgeon fork length (cm). Thus, food volume decreased from 0.93–0.01 %BM as fork length increased from 30–70 cm. All of the nine sturgeon captured in late March were without food in their stomachs.

Food overlap between size groups

Diets were remarkably similar across all length classes of sturgeon. Sturgeon of each length class contained primarily Ephemeroptera, Diptera, Trichoptera, Odonata and Annelida. An extremely high degree of dietary overlap was seen among stur-

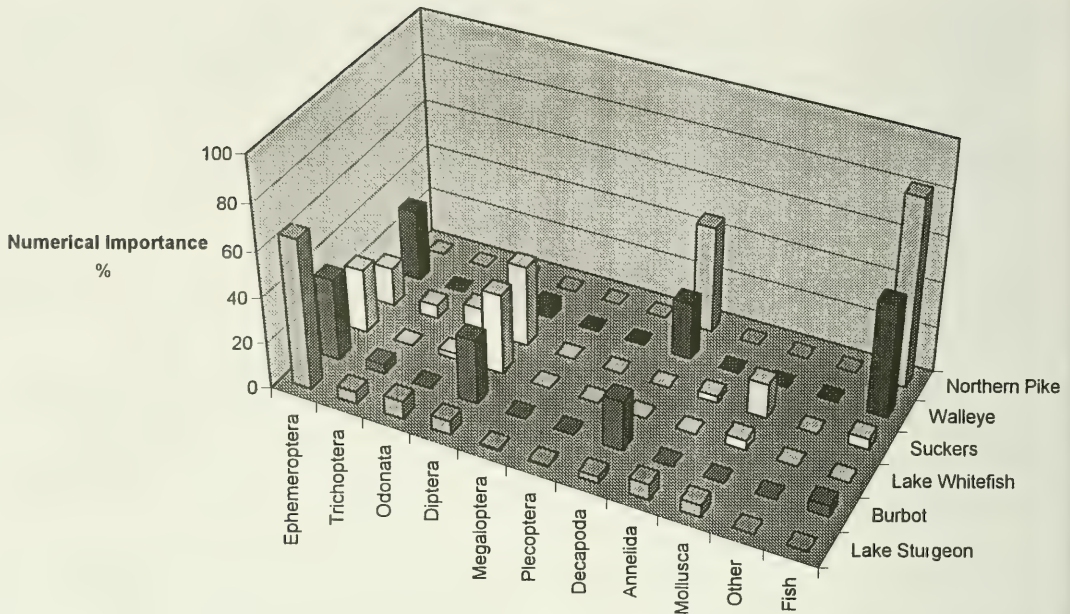


FIGURE 1. Numerical importance of prey categories in the stomachs of the major fish species captured by gill net in the Mattagami and Groundhog rivers.

geon of different length classes (Table 3). All length combinations showed diet overlap values well above the 0.6 level accepted as indicating a significant overlap in resource utilization. In all length class combinations, diet is essentially identical, with values exceeding 0.9, suggesting a high degree of food competition among all length classes of sturgeon examined.

Electivity indices (Table 4) showed strong positive values for Ephemeroptera in all length classes of sturgeon and for the population as a whole. Electivity values for most other categories were negative indicating either avoidance or inefficient foraging. Positive values were recorded in a few cells (e.g., Decapoda and Odonata) but these were largely associated with small sample sizes and may not be of biological significance.

Diet of other fishes

Stomach contents were examined for 109 fish. The number of White ($n=9$) and Longnose suckers ($n=4$) examined was small and the results for the two species were combined. Walleye, Northern Pike and suckers were of similar size, Lake Whitefish were larger and Burbot smaller (Table 5). Numerical importance and frequency of occurrence for Ephemeroptera and Diptera were high for Lake Whitefish, suckers and Burbot (Figures 1 and 2). Suckers also consumed appreciable numbers of Trichoptera, Odonata and Mollusca. Larger food particles, particularly Decapoda and small fishes were

especially important to Northern Pike, Walleye and, to some extent, Burbot. Small suckers and Walleye were the species most frequently consumed by these fishes. Spearman's rank order correlations indicated numerical importance did not differ significantly ($P > 0.05$) between Lake Sturgeon, suckers and Lake Whitefish, Burbot and Walleye, and Walleye and Northern Pike. Frequency of occurrence displayed similar correlations with the addition that dietary differences between Lake Sturgeon and Burbot were not significant.

Dietary overlap values indicated significant overlap between Lake Sturgeon and Lake Whitefish and Lake Sturgeon and Burbot (Table 5). Overlap was significant also between Lake Whitefish and suckers, Northern Pike and Walleye, and Burbot, suckers and Lake Whitefish.

Discussion

All sturgeon species are carnivorous throughout their life history (Buddington and Christofferson 1985). Sturgeon are believed to rely on a combination of olfactory, chemosensory, tactile, and electrosensory receptors rather than vision to forage for prey on, or just below, the surface of the substrate (Teeter et al. 1980; Buddington and Christofferson 1985; Zakon 1986). Electivity indices for Lake Sturgeon from the Mattagami and Groundhog rivers clearly indicated a preference for Ephemeroptera and provided little support of a preference for any of the

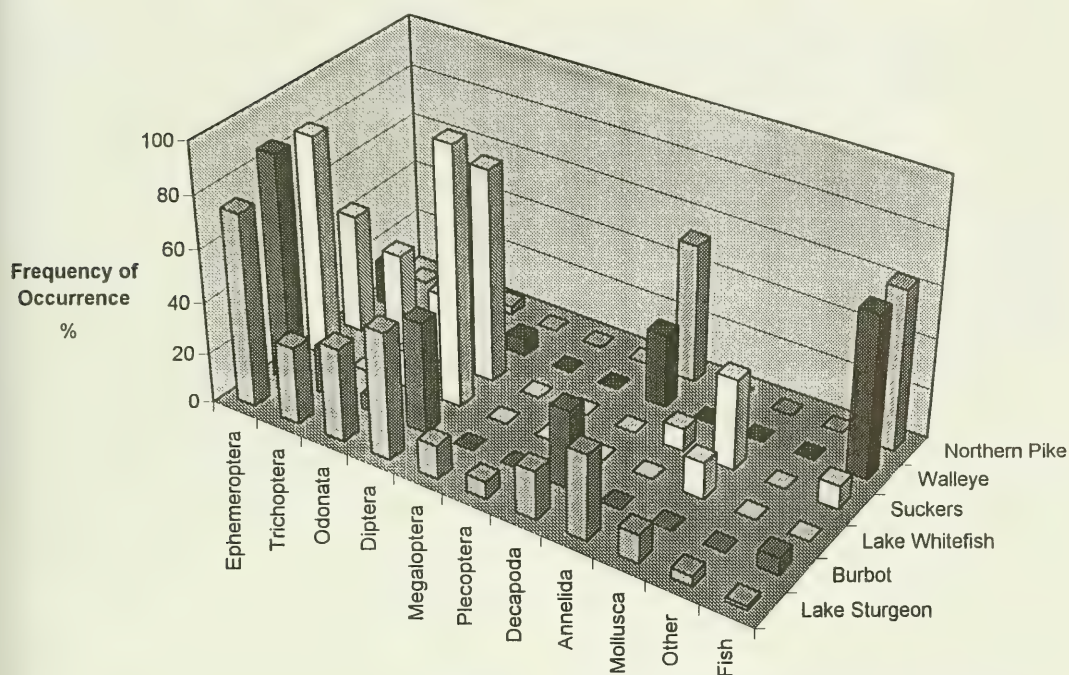


FIGURE 2. Frequency of occurrence of prey categories in the stomachs of the major fish species captured by gill net in the Mattagami and Groundhog Rivers.

other categories of benthic organisms. The negative values may, in some cases, reflect more on their habitat or availability than on their suitability for food. Thus, Annelida were most abundant in substrate consisting primarily of wood chips and cobble whereas juvenile Lake Sturgeon were most abundant over substrate dominated by sand and clay (Chiasson et al. 1997). In contrast Dipterans were abundant in the substrate but scarce in sturgeon stomachs which suggests they are avoided.

For many fish species, the type of food ingested varies with locality and season, reflecting the variable nature of the environment and food availability (Moore and Moore 1976b). Spring and summer diets have been described from other studies of Lake Sturgeon, but those studies were mostly qualitative and so can provide only a general comparison to our results. Sandilands (1987) reported that juvenile and adult Lake Sturgeon in the Kenogami River in northern Ontario ate mostly Trichoptera and Odonata larvae. Decapods were more common in the diets of larger fish (> 80 cm FL). In Lake Winnipeg, *Hexagenia*, Mollusca and Decapoda were the numerically dominant prey categories (Bajkov 1930). In the Opinaca, la Grande and Waswancipi Rivers in Quebec, Ephemeroptera larvae and Mollusca were most prevalent in the diet of Lake Sturgeon (Magnin 1977). Magnin and Harper (1970) reported that stur-

geon in Lake Waswancipi and the Waswancipi River ate mostly Trichoptera, Ephemeroptera, Diptera, Plecoptera and Odonata larvae. In Lake Pepin, Wisconsin, *Hexagenia* and other Ephemeroptera were dominant in the diet of sturgeon (Wagner 1908). In Lake Nipigon, Harkness (1923) reported the most important items in the diet were *Hexagenia*, Diptera and Mollusca. Based on the data from a number of lentic and lotic locations within Ontario, Harkness and Dymond (1961) reported that Ephemeroptera larvae were the major dietary component of Lake Sturgeon as was found in the present study, followed in importance by Mollusca and Decapoda. In Lake Winnebago during the winter, Diptera larvae were the dominant prey of Lake Sturgeon. Ephemeroptera, Megaloptera and Annelida represented only minor dietary components (Probst and Cooper 1955). Diptera were also dominant in the diet of sturgeon from smaller lakes near Winnebago (Butte des Morts, Poygan, and Winnecone) but Ephemeroptera and Megaloptera were of greater importance. These observations on winter diets contrast with those of the present study where all of the sturgeon examined were without food in their stomachs.

Sandilands (1987) provided tentative evidence for an ontogenetic shift in the diet of Lake Sturgeon in the Kenogami River, Ontario. However, we did not

detect any such dietary shift across the length range of juvenile Lake Sturgeon we examined. We found that food overlap was high for all size groups. One explanation for such extensive food overlap among all length classes of juvenile sturgeon is a seasonal occurrence of a superabundant resource (Seaburg and Moyle 1964; Zaret and Rand 1971), which lessens competition for resources. However, the extremely low population densities of all benthic taxa suggests rather that intraspecific competition for food may be severe. If this is correct the pattern of decline in relative volume of food in stomachs as body mass increased suggests small sturgeon may forage more effectively than large fish.

The macrobenthic fauna in the Mattagami and Groundhog Rivers while generally sparse in abundance varied considerably with substrate quality (Chiasson et al. 1997). Substrate dominated by the smallest particles, clay and sand, contained the greatest overall abundance of macroinvertebrates. Thus, *Hexagenia* abundance was approximately 50 individuals \times m⁻² in sand clay substrate whereas in other substrates numbers varied from 0 - 9 \times m⁻². Similarly, Diptera and Trichoptera densities were approximately 60 and 33 \times m⁻² in sand clay while in other substrates numbers varied from 7 - 17 and 3 - 5 \times m⁻², respectively.

Lake Sturgeon are not the only species in the Mattagami and Groundhog rivers that depend on the macrobenthos for food. Lake Whitefish, suckers, and, to some extent, Burbot displayed similar diets to that by sturgeon. The mean mass of suckers was about 70% of that of sturgeon, however, their relative abundance was more than twice that of sturgeon. Lake Whitefish and sturgeon were of similar mass but the former species was much less commonly captured by gill net. Burbot were relatively uncommon and of comparatively small size.

When prey densities are sufficiently low, a predator may switch to alternative, less desirable but more abundant prey items (Murdoch 1969; Schoener 1971; Stephens and Krebs 1986). However, all macroinvertebrates recorded in the benthos of the Mattagami and Groundhog rivers are being used by the fish. This situation may cause fish to forage in atypical habitats. For example, a few sturgeon consumed large numbers of gastropod molluscs. In rivers such as the Mattagami and Groundhog, where there is a considerable amount of silt, gastropods are usually associated with vegetation (Pennak 1954; Merritt and Cummins 1978). As the only vegetation we recorded was riparian or within small, shallow lagoons along the shoreline, we conclude that these individuals had been foraging in shallow water. We cannot tell from our results whether juvenile Lake Sturgeon show individually specific foraging tactics and prey preferences. However, our findings of a predominance of prey items of one species in a num-

ber of individual sturgeon suggest that this may occur.

Theoretical considerations of foraging tactics suggest that predators should select the largest available prey items if they are maximizing rate of energy intake (Schoener 1971; Stephens and Krebs 1986). Accordingly, we would predict a shift in prey size with increasing length of juvenile sturgeon and the accompanying increase in gape. However, we found no evidence for such a dietary shift, nor of any prey size selection throughout the length range of sturgeon. In our study the largest individual prey (Decapoda, *Orconectes propinquus*) in the benthos was consumed, by even the second smallest size group of sturgeon. The smallest taxa consumed, Diptera, were taken in approximately equal proportions throughout the entire length range of sturgeon.

We suggest that a limited food base in our study area, and an inherent inability to behaviourally partition the food that is available, has led to dietary overlap among several of the dominant fish species as well as among all length classes of juvenile sturgeon. This overlap likely represents competition for limited resources and the potential for a competitive bottleneck. Such a bottleneck may have a disproportionate effect on the regulation of population numbers or size distribution of a population. Our findings do highlight the importance of benthic invertebrates, especially larvae of the burrowing mayfly *Hexagenia*, for juvenile Lake Sturgeon in this area. This has significant consequences when coupled to our finding of the extremely low densities of benthic invertebrates in that area of the Moose River Basin. The slow growth rate of sturgeon in our study area (Beamish et al. 1996) is almost certainly a consequence of foraging on such a dispersed benthic food resource of such small unit size.

This section of the Moose River has a number of dams for hydroelectric production, and water flows are often highly regulated (McKinley et al. 1993). Any negative changes to the benthic fauna would be serious for the sturgeon. For example, *Hexagenia limbata* does not occur in organic sediments (Hunt 1953), and gomphid dragonfly nymphs, another prey item, prefer a grainy substrate with no organic flocs (Corbet 1962). Increased siltation from reduced river flow or increased organic input, would reduce the densities of these important benthic invertebrates.

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Using Snares to Live-Capture Beaver, *Castor canadensis*

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McKinstry, Mark C., and Stanley H. Anderson. 1998. Using snares to live-capture Beaver, *Castor canadensis*. *Canadian Field-Naturalist* 112 (3): 469–473.

Hancock and Bailey traps are typically used to live-capture Beaver (*Castor canadensis*) but are expensive and bulky. As an alternative capture method, we used steel cable snares to trap Beaver for a transplanting program from 1994 to 1997. Snares were used to capture 132 Beaver at 18 locations throughout Wyoming. Literature sources and communications with other live-trappers initially led us to believe that trapping with snares was not feasible or would lead to high mortality. Trapping success during our four years of trapping was 11.9 trap nights/Beaver. Mortality of Beaver captured in snares was 5.3%. Snares allowed us to saturate an area with traps and capture a large number of animals within a few days. Snares captured all size classes of Beaver, although we targeted larger animals by using larger snare sizes and setting the traps away from the lodge. Although our trap mortality rates with snares were higher than other researchers using Hancock and Bailey traps, snares are effective at live-capturing Beaver and may be useful where an effective, low-cost method of trapping is needed.

Key Words: Beaver, *Castor canadensis*, Bailey trap, Hancock trap, live-trapping, snares, trap.

Beaver are often live-trapped for transplanting (Brayton 1984; Butler 1991) or research purposes (Lancia et al. 1982; Dyck and MacArthur 1992; Nolet and Rosell 1994; van Deelen and Pletscher 1996). The most common methods of live-trapping Beaver are either Hancock or Bailey live-traps (Rawley 1954; Olson and Hubert 1994; Smith et al. 1994). Padded leg-hold traps have also been used but they often inflict permanent injuries (Phillips et al. 1996). Snares have been suggested as a kill method by several authors (Barringer 1992; Collins 1993; Olson and Hubert 1994; Krause undated) but they have not been reviewed as a viable method for live-trapping.

In 1994 we began a transplanting project in Wyoming to establish Beaver in areas where land-managers wanted to create lentic habitat in otherwise lotic systems. We originally planned to trap Beaver exclusively with Hancock and Bailey live-traps because communications with other researchers and trappers led us to believe that snare trapping would be lethal to Beaver. Predation and emigration of our transplanted Beaver exceeded 80% (McKinstry and Anderson 1997; McKinstry and Anderson *in press*) and we found that Beaver establishment was more likely if we released > 10 Beaver at each site. Since we needed a large number of animals to increase our probability of success, and we were holding the animals for several days before their release, we required a substantial trapping effort. Hancock and Bailey traps were cumbersome and expensive, thus preventing us from using a large number of traps to saturate a trapping area and capture a large number of Beaver. We therefore decided to evaluate the effectiveness of using snares to live-trap Beaver.

Methods

We trapped Beaver from 1994 to 1997 at 18 creeks and streams throughout Wyoming (Table 1). Trapping locations were concentrated on Beaver dams and ponds, although we also trapped in irrigation canals. Beaver were not trapped from free-flowing portions of rivers or in areas where dams and lodges had not been constructed. Stream flow at all trapping locations was less than 1.5 m³/sec.

Snares (Figure 1) were constructed of 7 by 7 strand or 7 by 19 strand (7 by 19 preferred but more expensive) 2.38 mm (3/32 in) stainless steel aircraft cable. Snare leads, which allowed the animal some freedom to move around yet still remain anchored, were constructed of 7 by 7 strand, 6.35 mm (1/4 in) cable (Figure 1). Snare cables were cut 1m long and leads were 1m or greater. Swivels (M and M Fur Company, Bridgewater, South Dakota, USA; reference to trade names or companies does not constitute endorsement), which allowed the snare to remain tangle-free after an animal was captured, were installed at both (1) the end of the snare cable where they were held in place with a washer and cable stop and (2) at the end of the lead where they were used as an attachment to the stake (Figure 1). Snares were stripped of parts (which often could be re-used) and discarded after a capture, while leads were re-used to reduce trapping costs. Various snare locks were used including modified washer locks (Burkshire Products Inc., Sheffield, Massachusetts, USA), KAM locks (Slutker Furs, Edmonton, Alberta, Canada), and BMI cam and slide-free locks (Butera Manufacturing Industries, Willoughby Hills, Ohio, USA) (Figure 1). Aluminum cable sleeves and stops were crimped in the field with a swaging tool which allowed us to customize snares for different trapping conditions.

TABLE 1. Latitude and longitude, dominant vegetation, and stream classifications (using Rosgen's [1994] classification) for 18 creek Beaver trapping locations in Wyoming.

Stream Name	Latitude, Longitude	Dominant Vegetation	Stream Classification
Barrett Creek	41°20'N, 106°31'W	Willow (<i>Salix</i> spp.)	B3
Brush Creek	41°37'N, 106°37'W	Cottonwood (<i>Populus</i> spp.) and willow	B3
Brush Creek	41°38'N, 106°33'W	Willow	
Calf Creek	41°14'N, 106°54'W	Conifer and willow	A3
Cheyenne River	43°27'N, 104°30'W	Cottonwood	F5
Cheyenne River	43°32'N, 104°43'W	Cottonwood	F5
East Fork, Medicine Bow River	41°32'N, 106°25'W	Aspen (<i>Populus tremuloides</i>) and willow	B3
Flat Creek	43°28'N, 110°47'W	Willow	D/A4
Henry's Fork, Green River	41°03'N, 110°13'W	Cottonwood and willow	C3
Middle Branch, Middle Lodgepole Creek	41°43'N, 105°25'W	Willow	B4
Middle Fork, Little Laramie River	41°14'N, 106°5'W	Willow	C4
One Mile Creek	41°36'N, 106°12'W	Willow	B3
Mill Creek	41°31'N, 106°25'W	Willow	C4
Sourdough Creek	44°14'N, 107°58'W	Willow	B3
Turpin Creek	41°31'N, 106°25'W	Aspen, conifer, and willow	B3
Wagonhound Creek	41°37'N, 106°19'W	Willow	B4
Wolf Creek	44°50'N, 107°41'W	Cottonwood and willow	C3

Snares were set so that an approximately 27 cm diameter loop was resting on the ground perpendicular to travel and were supported by wrapping bailing wire around both the swivel end of the snare and a support stick that was placed perpendicular and upright to the trail (Figure 1). Beaver are very habitual in their use of travel corridors. We found trails and runs located throughout Beaver territories and it was easy to predict trails that were being used by examining the trail for wet areas, disturbed sediment, footprints, and drag marks. Snares were placed in Beaver runs over dams, in Beaver-excavated canals, in runs out of the water (generally leading to feeding areas), and at underwater lodge entrances. We often used sticks or other materials to "funnel" Beaver into a snare, although too much material often forced the animal around the run into a different trail.

We began trapping after ice-off in the spring (usually mid May) and concluded trapping by the second week in October depending upon ice and snow conditions. All traps were set between 1600 and 1900 h each day and were checked by 0930 h the following morning to minimize the time spent captured. We usually set between 10 and 15 snares/ trapper/night; more than that and it was difficult to both check them early enough and find them in the thick willows (*Salix* spp.) where we were trapping. Animals captured in snares were first restrained using a 1.5 m catch pole (M and M Fur Company, Bridgewater, South Dakota), then transported from the trap site using a 114-l plastic garbage bag bolted to a backpack frame. We sexed

and measured Beaver while they were restrained with the catch pole and weighed and eartagged

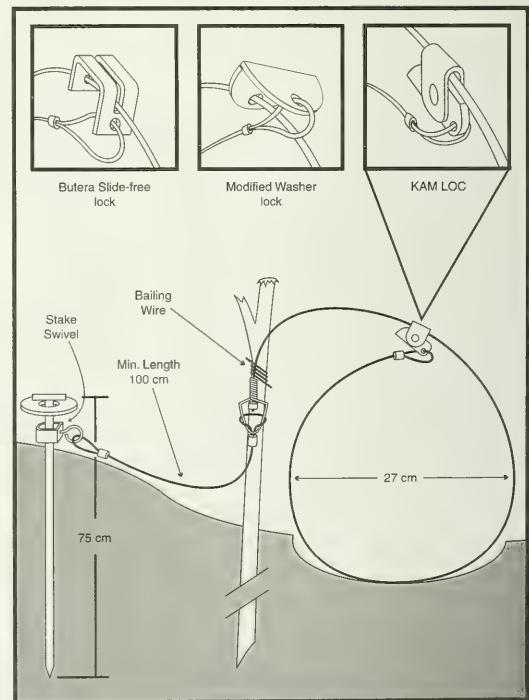


FIGURE 1. A completed snare showing several types of locking mechanisms, swivels, lead, and stake.

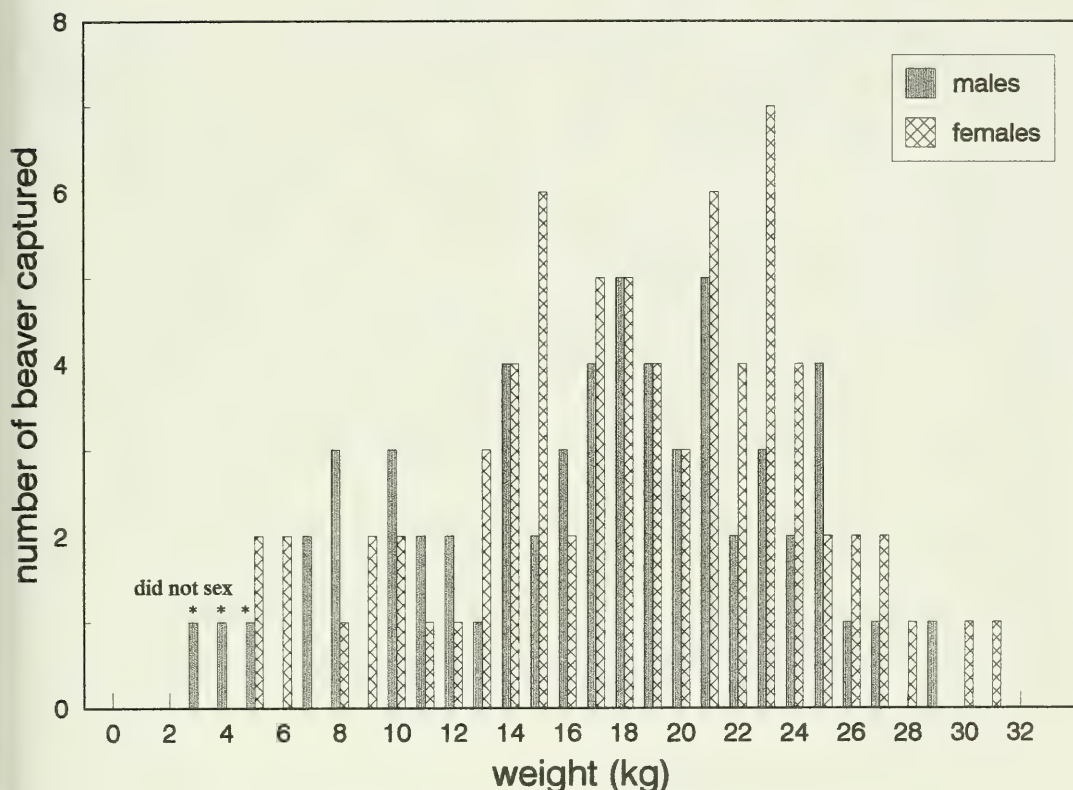


FIGURE 2. Frequency of Beaver captures per weight (kg) and sex categories.

them while they were in the garbage can. Snares were removed from Beaver with a pair of cable cutters (M and M Fur Company, Bridgewater, South Dakota).

We used a z test (Jandel Scientific 1994) to test proportional differences in captures of males versus females. Tests were considered significant at $P \leq 0.05$.

Results

We captured a total of 132 Beaver in 1568 trap nights. Catch-per-unit-effort averaged 11.9 trap nights/Beaver or 8.4% (the probability of an individual trap's capture). Average weight of animals captured in snares was 17.7 kg (range 2.7 to 31 kg, $SD = 6.07$) and there was no difference in proportion of males (0.44) or females (0.56) captured ($z = 1.23$, $P = 0.22$) (Figure 2). Only five kits (< 4.5 kg) were captured in snares. Sets made at dam crossovers accounted for 74 percent of all snare captures. Runways on dams are relatively easy to identify and are used heavily by Beaver in their daily activities. Snares set in land runways, generally areas where Beaver were exiting the water to feed, were also productive, accounting for 16 percent of snare captures.

Seven (5.3%) Beaver died while restrained in snares. Two of these were killed by Coyotes (*Canis latrans*) and another was killed by a second Beaver. The remaining four Beaver were entangled in vegetation and the animal either suffocated (2) or drowned (2). While we have no information on health of Beaver captured in snares, 111 Beaver captured in snares were eventually released at transplant locations, of which 58 were equipped with transmitters and monitored. Fifty-five transmitted Beaver lived > 7 days post-release. The other three Beaver were killed by predators (conclusions based upon bite marks, subcutaneous hemorrhaging, and hair and tracks found at the site) within four days of release. All Beaver that we captured actively fed while they were held in captivity (< 5 days) until release and appeared healthy at the time of release.

Captured animals were usually located out of the water when the traps were checked. Often the vegetation within the radius of the snare had been cut during the animal's attempts to extricate itself. Beaver were aggressive when we attempted to remove them from the snare and caution was needed to prevent being bitten. Generally, Beaver were snared around the chest or abdomen although several animals were snared at the base of the tail.

We also captured two Muskrats (*Ondatra zibethica*), one Coyote, one Raccoon (*Procyon lotor*), and two Common Mergansers (*Mergus merganser*) in our snares. Except for one Muskrat, which appeared to have died from strangulation, none of the non-target animals were physically impaired.

Discussion

Except in the fur-trapping literature, little mention is made of the use of snares for capturing Beaver. Organ et al.'s. (1996:16) coverage of trapping and furbearer management only mentions "box (cage-type) traps and foothold traps" as viable live-trapping techniques. Rawley's (1954) manual, while somewhat dated, makes no mention of the use of snares for live-trapping Beaver. Similarly, Harris and Aldous (1946), Townsend (1953), and Olson and Hubert (1994) give significant coverage to live-trapping Beaver with Hancock and Bailey traps but do not mention other methods of capture. Anecdotal mention of catching Beaver live in snares is made in both Krause's (undated) and Barringer's (1992) books, but they imply that it is an uncommon occurrence. Riedel (1988) focuses on snares as a lethal means of Beaver control, but does not mention their use as a live-trapping method. Riedel's (1988) snares were different from ours in that his did not have leads, entanglement opportunities were emphasized to hasten mortality, and snares were tied off with heavy wire or hung from trees or branches and did not release to allow the animal some movement.

Mortality in our snares was higher than that reported by other researchers using Hancock or Bailey traps. Smith et al. (1994) experienced 4.2 % predation (Black Bears [*Ursus americanus*]) of Beavers captured in Hancock traps on an island in Lake Superior and Smith and Peterson (1988, in Smith et al. [1994]) only had one Beaver killed (Black Bear) in over 1500 captures in Voyageurs National Park. Using Hancock and Bailey traps, Collins (1976) captured over 100 Beaver in and around the Snake River in northwest Wyoming with no mortalities. Hancock and Bailey traps do offer some protection and it might be difficult for a predator smaller than a Black Bear to kill a Beaver restrained in one. Mortality from predators is difficult to eliminate but could be reduced by checking traps frequently (e.g., every four hours). Entanglement accounted for four mortalities in our research. Two Beaver were entangled in sets at underwater lodge entrances and two more in areas with dense vegetation. Snare sets made in these locations are risky and mortality can be reduced by avoiding these sets. We were trying to catch mated pairs and family units in 5 days or less, so we were willing to accept higher mortality rates in the hope of catching a specific animal. In situations where mortality would bias research results or is socially unacceptable, trappers should eliminate entanglement

possibilities when making sets or forgo the use of snares altogether.

We captured all size classes of Beaver in snares (Figure 2) although kits were not captured as frequently as the larger adults. Our difficulty in capturing kits was probably due to the large loop size in the snares we were using. We were not targeting kits for capture but the use of a smaller snare loop could increase kit captures if that is a goal; although it would probably reduce the capture of larger animals since they would not fit through the smaller snare loop. Additionally, kits primarily use habitat that is in close proximity to the lodge and generally do not travel away from the den pond during their first year (Hodgdon and Lancia 1983). The majority of our snares were not located near the lodge where the kits would be more susceptible to trapping.

We wanted to trap a large number of Beaver, generally > 6, in a short period of time (< 5 days), at each site for later transplanting. We found that Hancock and Bailey traps, due to their cost and bulk, did not provide the trapping capabilities and efficiency that we needed. Snares allowed us to saturate an area with traps and increased the opportunities for catching more Beaver. We feel this method is suitable for use where the higher mortality risk for Beaver is acceptable.

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Breeding Ecology and Status of the Red-necked Grebe, *Podiceps grisegena*, in the Subarctic of the Northwest Territories

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The breeding ecology of the Red-necked Grebe, *Podiceps grisegena*, was investigated on a 38-km² study area near Yellowknife, Northwest Territories (62° 27'N, 114° 22'W). Population size and productivity were monitored during 1986-1996, whereas other aspects of breeding ecology were studied opportunistically. The mean breeding population was 59 pairs, representing a density of 1.6 pairs/km². The mean size of ponds used for breeding was 3.7 ± 0.2 (SE) ha. Plants most commonly used as cover and support at nests were cattail (*Typha latifolia*), sedge (*Carex* spp.), willow (*Salix* spp.), and horsetail (*Equisetum fluviatile*). Nests were constructed of emergent and submergent plants, most commonly sedge, sphagnum moss (*Sphagnum* spp.), cattail, horsetail, and pond lily (*Nuphar variegatum*). Nests were generally located well away from the shore (mean distance from shore: 14.8 ± 1.7 m), within the emergent vegetation zone but close to open water (mean distance to open water: 1.5 ± 0.3 m). Mean depth of water at nests was 63 ± 3 cm. We observed an average clutch size of 4.4 ± 0.1 eggs, average brood success of 72%, and a production rate of 2.0 young per successful pair or 1.4 young per breeding pair. These values are similar or slightly higher than those reported for the species elsewhere in North America. Our results, in addition to information from other published and unpublished sources, indicate that the Red-necked Grebe is abundant and has a widespread distribution in the southwestern Northwest Territories. The Northwest Territories breeding population appears to be a significant component of the national population of this species.

Key Words: Red-necked Grebe, *Podiceps grisegena*, subarctic, boreal forest, breeding, population density, productivity, status, Northwest Territories.

The Red-necked Grebe, *Podiceps grisegena*, is a holarctic species with two distinct races. *Podiceps grisegena grisegena* occurs in eastern Europe and western Asia and *Podiceps grisegena holboellii* occurs in eastern Asia and northwestern North America (Johnsgard 1987; del Hoyo et al. 1992). In North America, the breeding distribution of the Red-necked Grebe encompasses much of western Canada including the western Northwest Territories (Godfrey 1986; Johnsgard 1987). Despite this wide breeding range, few studies of Red-necked Grebes have been undertaken, and these have been concentrated in sub-boreal parkland habitats (e.g., Kevan 1970; Riske 1976; De Smet 1983). Little has been previously reported regarding the abundance or ecology of this species in the subarctic boreal forest or the Northwest Territories.

During 1986-1996, we monitored the population size and productivity of Red-necked Grebes near Yellowknife, Northwest Territories, as part of a long-term study of subarctic waterfowl. Opportunistically, we investigated various aspects of the breeding ecology of these birds in greater detail. Our objective was to provide basic biological information on this infrequently studied species from a geographic region in which its status and ecology were virtually unknown.

Study Area

The primary study area consisted of a 38-km²

roadside transect beginning approximately 16 km west of Yellowknife, Northwest Territories (62° 27'N, 114° 22'W), continuing approximately 48 km west, and extending 0.4 km on each side of the road. There were 575 ponds on the primary study area; 262 were natural in origin and 313 were man-made (borrow pits) created during construction of the highway circa 1960. The median pond size was 0.2 ha for natural ponds (range <0.1-18.2 ha), <0.1 ha for borrow pits (range <0.1-1.10 ha), and 0.1 ha overall. Borrow pit ponds were shallow and semi-permanent in nature and provided approximately 38 ha of wetland habitat. Natural ponds encompassed approximately 292 ha and were generally deeper and permanent.

To increase sample sizes we also gathered data for Red-necked Grebes nesting on ponds within a 20 km radius of Yellowknife, but outside the primary study area. We refer to this as the secondary study area.

The entire study area is within a zone of open subarctic woodland in the Boreal Forest Region (Rowe 1972). The climate is typically subarctic-continental and is characterized by long cold winters and short cool summers. Most ponds become ice-free by mid-May, but larger natural ponds retain ice until late May. The open water season extends approximately 120-130 days, and most ponds are frozen by late September. Long hours of daylight occur during the grebe breeding season. For example, on 21 June

(summer solstice) the sun is above the horizon for about 20 hrs and twilight prevails during the remaining four hours.

Methods

We conducted ground surveys of the primary study area from 1986 to 1996 using methods described by Murdy (1965*). The dates that surveys were conducted varied from year to year with variation in the chronology of spring break-up and the subsequent breeding season of waterfowl. Surveys occurred in mid-late May (earliest 12-13, latest 24-26), early June (earliest 5-8, latest 10-12), July (earliest 3-5, latest 23-26), and August (earliest 6-8, latest 19-22). We conducted each survey over a 3-4-day period between the hours of 06:00 and 10:30. We surveyed 13 of the largest natural ponds by canoe, whereas all other ponds were surveyed by walking. All grebes observed were recorded on 1:7500 scale maps of the study area.

Breeding pair estimates were derived from the numbers of pairs and broods observed on the primary study area during the June, July, and August surveys. A breeding pair was assigned to each pond where a pair or brood was observed during one of the surveys. Grebes observed during May surveys were excluded from the calculation of pair estimates as migration and selection of breeding ponds may not have been completed at this time.

Numbers of broods were derived from July surveys of the primary study area, plus any new broods observed in August. The greatest number of young observed on either survey was assigned as the brood size for that pond. This approach was necessary due to the protracted period of hatching, a result of asynchronous hatching and reneesting following loss of initial nests.

Probable nesting ponds were identified from the surveys of the primary study area and from personal observations (MAF) on the secondary study area. Grebe nests were then located by wading or canoeing the emergent vegetation. At each nest, we recorded the plants used in nest construction and those providing cover and support. Water depth was calculated as the mean of four measurements, to the nearest cm, taken at cardinal points around the nest. Distance of the nest from shore and from open water were measured (to the nearest 0.1 m) at the water surface using a 2-metre measuring stick (used also to measure depth). These distances were not measured in 1993 and sample sizes are thus smaller than those for other nest site characteristics.

All ponds on which grebe pairs or broods were recorded during June, July, and August surveys of the primary study area were classified as breeding

ponds and were included in the analyses of pond type (natural versus man-made) and size (area). Pond size was determined from 1:7500 scale aerial photographs using a dot-grid overlay.

Clutch-size and egg-size data were collected on the primary and secondary study areas. All eggs were measured (maximum length and width) to the nearest 0.1 mm with calipers. Clutches were considered to be complete when the number of eggs remained constant during consecutive visits at least four days apart. Clutches that were destroyed before we could verify they had been completed were excluded from the calculation of clutch size.

Date of clutch initiation was estimated by back-dating at a rate of one egg laid every two days (De Smet 1982, 1983). Hatch date was defined as the date of hatch of the first egg in a clutch. If more than one egg had hatched between consecutive visits we estimated hatch date by back-dating based on the number of eggs remaining in the nest and assuming a hatch rate of 1.5 eggs per day (De Smet 1983).

Results

The average date of arrival of the first grebe(s) on the primary study area during 1986-1996 was 10 May (range 6 May - 16 May). Peak numbers occurred one to two weeks later, at which time groups of 10-20 Red-necked Grebes (mostly paired) occupied medium-sized ponds that were free of ice, or open water areas in larger ponds.

The mean number of breeding pairs on the primary study area was 59 (range 50 - 72; Table 1), representing an average density of 1.6 pairs per km² (range 1.3 - 1.9).

Breeding Red-necked Grebes were recorded on 110 of 575 ponds available on the study area. Of these, 97 were natural ponds (37% of 262 available) and 13 were man-made (4% of 313 available). The mean size of ponds used was 4.0 ± 0.2 (SE) ha for natural ponds (range 0.1 - 18.2 ha, median 2.9 ha, $n = 498$), 0.4 ± 0.03 ha for man-made ponds (range 0.05 - 1.1 ha, median 0.4 ha, $n = 39$), and 3.7 ± 0.2 ha (median 2.4 ha) overall.

Only seven ponds that were less than 0.3 ha in size were occupied, despite the abundance of such ponds on the study area ($n = 409$; Figure 1). Five of these were connected to much larger ponds by short narrow channels and the remaining two were surrounded by other ponds forming a complex of wetlands. The percentage of available ponds used generally increased with pond size (Figure 1) to a maximum of 81% for ponds > 4.0 ha.

Of 89 nests examined, all were anchored to emergent vegetation. The most commonly used emergents were cattail (*Typha latifolia*), sedges (*Carex* spp.), willows (*Salix* spp.), and horsetail (*Equisetum fluviatile*) which were used at 39%, 20%, 18%, and 15% of nests, respectively. The

*see Document Cited section.

TABLE 1. Observed population size and productivity of Red-necked Grebes on the primary study area, 1986-1996.

Year	Breedings Pairs	Broods	Brood Success (%)*	Total Young	Young Per Successful Pair	Young Per Breeding Pair
1986	54	33	61	68	2.06	1.26
1987	52	36	69	81	2.25	1.56
1988	57	29	51	46	1.59	0.81
1989	50	41	82	92	2.24	1.84
1990	61	39	64	73	1.87	1.20
1991	66	43	65	83	1.93	1.26
1992	65	53	82	110	2.08	1.69
1993	60	51	85	91	1.78	1.52
1994	72	56	78	109	1.95	1.51
1995	54	40	74	88	2.20	1.63
1996	61	49	80	93	1.90	1.52
AVG	59	43	72	85	1.99	1.44

*Brood success = broods / breeding pairs \times 100.

remaining nests were anchored to bulrush (*Scirpus* spp.), Water-arum (*Calla palustris*), Marsh Cinquefoil (*Potentilla palustris*), flooded (dead) alder (*Alnus* spp.), and Yellow Pond-lily (*Nuphar variegatum*). Nests were constructed of a variety of plant materials, including sedges in 75% of the nests, sphagnum mosses (*Sphagnum* spp.) in 60%, cattail in 43%, horsetail in 29%, and pond-lily in 26%.

Characteristics of nest locations are provided in Figure 2. Of 48 nests for which distances were measured, the mean distance from shore was 14.8 ± 1.7 m (range 3.1 - 65.0 m, median 12.0 m) and mean distance to open water was 1.5 ± 0.3 m (range 0 - 12.5 m, median 0.7 m). All nests were farther than 3

m from shore and 90% were located within 3 m of open water. Mean water depth at nests was 63 ± 3 cm (range 16 - 163 cm, median 61 cm, $n = 89$).

We were able to estimate clutch initiation dates for 32 nests found during the laying period. These clutches were initiated from 21 May to 21 June, with a median date of 31 May. However, 27 (84%) of these were initiated between 24 May and 5 June. At least one of three nests initiated on or after 12 June was a re-nest.

Clutch size was determined for 80 nests, 28 of which were found during the laying period and 52 found after laying was completed (17 clutches were destroyed before clutch size could be determined).

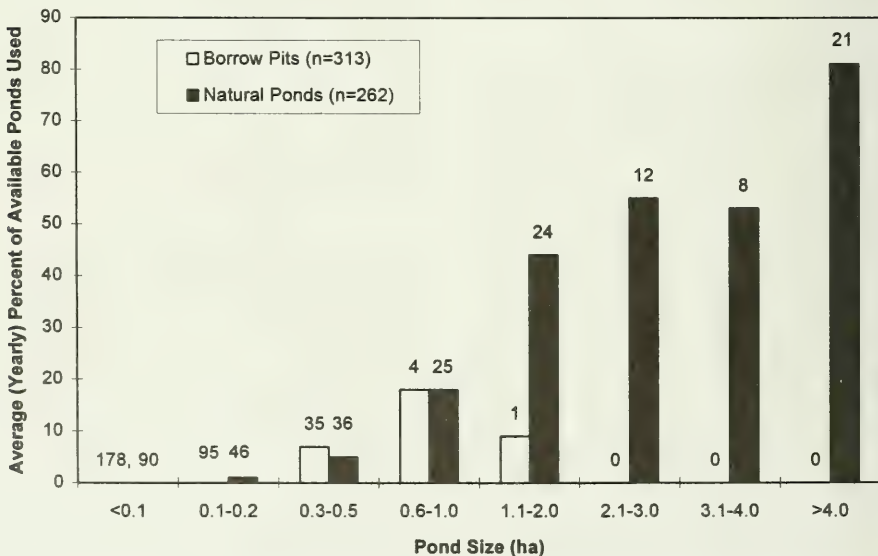


FIGURE 1. Size of ponds used for breeding by Red-necked Grebes. Numbers above bars indicate the number of man-made (borrow pit) and natural ponds available in that size category.

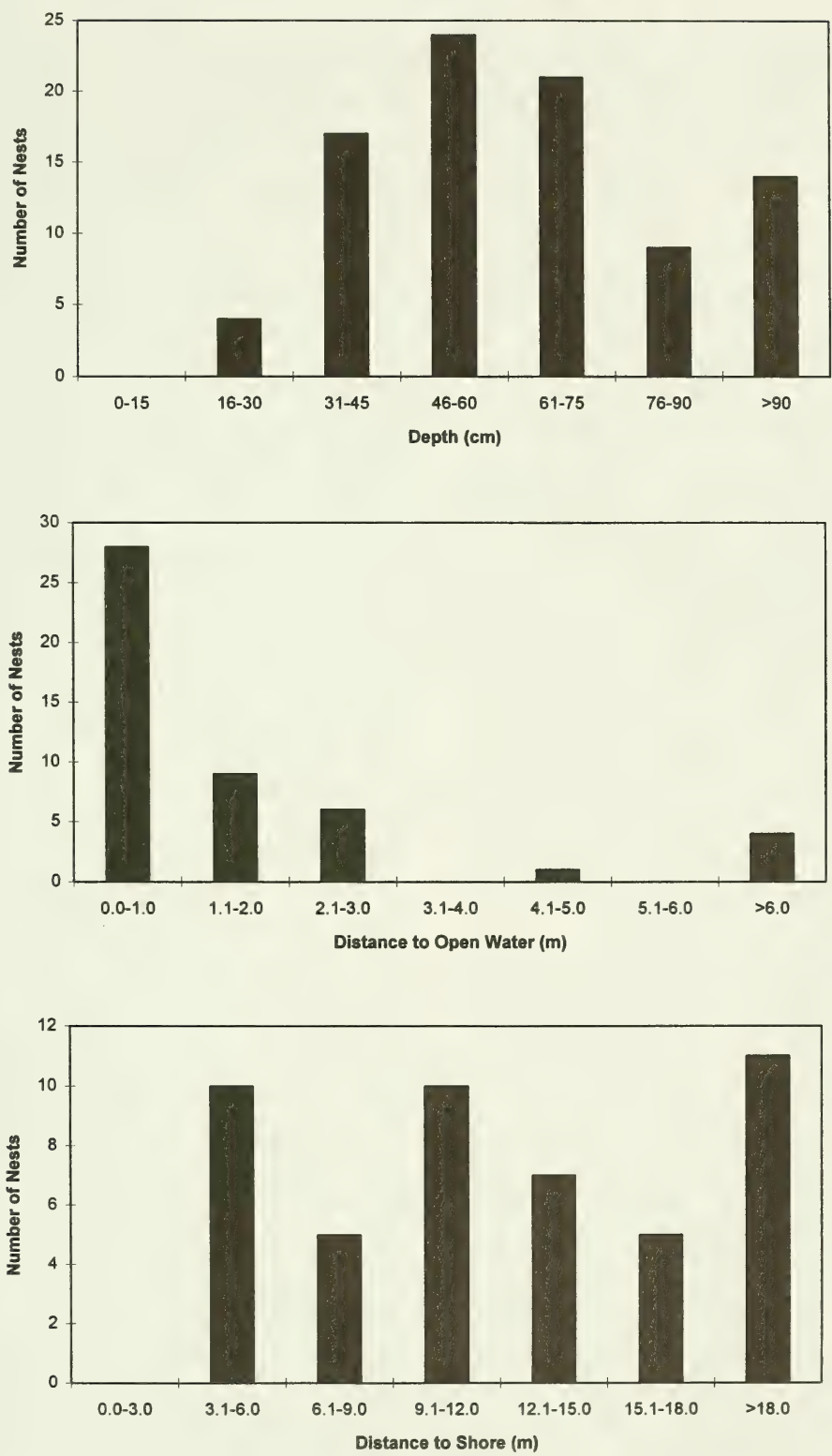


FIGURE 2. Characteristics of Red-necked Grebe nest sites.

TABLE 2. Red-necked Grebe clutch sizes in the Yellowknife region, 1986, 1988-89, 1991-93.

Year	Mean Clutch Size	Standard Error	Range	Sample Size
1986	4.58	0.19	3-6	19
1988	4.29	0.52	3-7	7
1989	3.33	0.33	2-4	6
1991	4.17	0.31	3-5	6
1992	4.00	0.17	3-5	12
1993	4.67	0.18	2-7	30
All Years	4.38	0.11	2-7	80

Clutch sizes ranged from 2 to 7 eggs with an overall mean of 4.4 ± 0.1 eggs ($n = 80$; Table 2). However, there was a significant difference (t-test, $t = 2.12$, $df = 78$, $P = 0.04$) between the size of clutches found during laying and those found after laying was complete, with means of 4.7 ± 0.2 and 4.2 ± 0.1 , respectively. This suggests that egg loss or partial destruction of clutches by predators may have gone undetected in some clutches not discovered until after laying was complete.

The mean length of eggs was 53.5 ± 0.2 mm and the mean width was 35.3 ± 0.1 mm ($n = 333$). Hatch of the first egg in a clutch occurred predominantly between 13 June and 1 July with a median date of 21 June ($n = 27$). In twenty-two of these clutches (81%) hatch began between 17 June and 28 June.

Brood success ranged from 51% in 1988 to 85% in 1993 and averaged 72%. The average number of young produced per year on the primary study area was 85 (range 46 - 110), representing approximately 2.0 young per successful pair (range 1.6 - 2.3) or 1.4 young per breeding pair (range 0.8 - 1.8; Table 1).

Discussion

In general, nest site selection of Red-necked Grebes is dependent upon several inter-related factors: composition and density of vegetation, depth and size of water bodies, and subsequent protection from wind/wave action, and predators (Ohanjanian 1986). In most aspects, habitat selection recorded on our study area (types of plants used and location of nests) was similar to that reported in other North American studies (e.g., Kevan 1970; De Smet 1983). However, there were some noteworthy differences.

In North America, Red-necked Grebes have been reported to prefer shallow lakes, usually not less than 2-4 ha in extent, for nesting (Munro 1941; Riske 1976; De Smet 1982*; Johnsgard 1987). Our data support this observation in that a greater percentage of the ponds available in size categories ≥ 2.1 ha were occupied when compared to smaller size categories (i.e., these ponds appeared to be preferred). However, approximately 41% of all ponds utilized on our study area were less than 2 ha in size and only 35% exceed-

ed 4 ha in size. This suggests that in parts of North America Red-necked Grebes may be more flexible in their choice of nesting lakes and ponds than was previously reported. The smaller European race of Red-necked Grebes also uses small, boggy lakes or ponds (Sage 1973) similar in size and nature to some of those on our study area. Near Yellowknife, Red-necked Grebes also use wetlands bordering slow-flowing rivers for nesting (MAF personal observations) a habit recognized in some (Sage 1973; Godfrey 1986) but not all (De Smet 1982*; Johnsgard 1987) reviews on the species.

The average clutch size (4.4) of Red-necked Grebes nesting on our study area was similar to values reported in previous studies (4.6, Kevan 1970; 4.2, Riske 1976; 5.0, De Smet 1983; 4.1, Ohanjanian 1986). The number of young produced per successful pair on the primary study area was similar to that reported by De Smet (1983) and Kevan (1970) (approximately 1.9 in all cases) but was higher than that observed by Riske (1976) (1.4 for lake and 1.6 for potholes). The number of young produced per breeding pair (1.4) was higher than other studies (1.1, Kevan 1970; 0.4 and 1.1, Riske 1976; 0.9-1.0, De Smet 1983). Therefore, productivity of this boreal forest nesting population appears to be equal to or slightly higher than in other areas.

Status of the Red-necked Grebe in the Northwest Territories

Although the distribution of the Red-necked Grebe in the Northwest Territories (NWT) has been identified in a general sense (Godfrey 1986), a detailed account does not exist in recent literature. We examined published and unpublished information to provide a better understanding of this species distribution and abundance in the region. The Red-necked Grebe occurs over a very broad area, from the Slave River Lowland (Preble 1908; Soper 1957), throughout the Mackenzie River drainage basin (Baird et al. 1884; MacFarlane 1908; Preble 1908; Soper 1950*; Salter and Davis 1974; Thompson 1975; Scotter et al. 1985), north to the Mackenzie Delta (Porsild 1943). Several authors reported it common in portions of this range (Preble 1908; Soper 1950*), including at its northern limit of distribution in the inner Mackenzie Delta (Porsild 1943), and most provided evidence of breeding (MacFarlane 1908; Preble 1908; Porsild 1943; Salter and Davis 1974; Thompson 1975; Scotter et al. 1985).

There are few estimates of population densities for Red-necked Grebes in the literature, and no published information for boreal forest breeding areas, or the NWT. In the region north of Great Slave Lake, similar breeding densities to those we observed (3.2 birds/km²) probably occur well beyond the boundaries of our study area. However, such densities are

not representative of the entire range in the NWT. For example, the population density for a 700 km² wetland area surrounding Brackett Lake (65° 06'N, 125° 19'W) averaged 0.48 birds/km², and for a 1400 km² area of wetlands near the mouths of the Hume and Ramparts rivers (approximately 66° 00'N, 129° 00'W) the density was 0.08 birds/km² (data from aerial surveys conducted during 1993-1996 and 1997 respectively, D. Kay, Ducks Unlimited, personal communication). These data, in conjunction with ours, suggest a decreasing trend in Red-necked Grebe densities with increasing latitude.

Other data provide an indication of general abundance in the NWT. Sirois (1993) estimated a peak number of 2100 Red-necked Grebes were present on shoreline marshes of the North Arm of Great Slave Lake during spring migration in May 1990. Allowing for turnover during the migration period (surveys were conducted every 3-4 days from 10 May to 30 May) these data suggest that several thousand Red-necked Grebes pass through this region on their northward migration. Further, aerial surveys of breeding waterfowl in the western NWT (conducted by the U.S. Fish and Wildlife Service, 1980-1982) produced a minimum population estimate of 20 172 Red-necked Grebes (V. Stotts, undated^{*}). Despite possible limitations of Stotts' data (small number of transects, uncertain visibility bias) we believe they provide a plausible assessment of the numbers of Red-necked Grebes that occur in the region during the breeding season.

De Smet (1982*) calculated a conservative population estimate of 5500+ breeding adult Red-necked Grebes in Canada, but suggested that more widespread and accurate population surveys would produce an estimate in excess of 20 000 breeding birds. The data we present above suggest that; (1) the NWT population alone probably exceeds 5500 breeding birds, (2) the Canadian breeding population must therefore be much higher, and (3) the NWT may support a significant portion of the Canadian breeding population of this species.

Assuming no major losses occur during migrations or on wintering areas, the status of Red-necked Grebes in the NWT appears secure because of their widespread distribution in the region, an average to high level of productivity, and a lack of significant threats to breeding habitat.

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Status of the Bearded Owl-clover, *Triphysaria versicolor* ssp. *versicolor* (Scrophulariaceae), in Canada*

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In British Columbia, *Triphysaria versicolor* ssp. *versicolor* populations are found only on Vancouver Island near Victoria, where eight extant populations are known. Historic records suggest that this taxon has declined in this area since the early part of this century. Half of the populations occur on private land and half occur in city parks. The latter populations face more threats than those on private land, as there are no covenants in place to protect them; instances are known where rare plants have been destroyed by "improvements," such as the building of benches or trails. On private land, rare plant survival is at the discretion of the home owners. Introduced species, which are widely distributed in the Victoria area, also may pose a threat to the continued persistence of some populations. Private land stewardship programs and park covenants would prove useful in the conservation of *Triphysaria versicolor* ssp. *versicolor*, as well as the other rare plants that occur in these habitats.

Key Words: Bearded Owl-clover, *Triphysaria versicolor* ssp. *versicolor*, endangered, distribution, population, British Columbia.

Triphysaria (Scrophulariaceae, tribe Pedicularae, subtribe Castillejinae) is a western North American genus consisting of five species of annual herbs. The subtribe Castillejinae, to which it belongs (which also includes *Castilleja*, *Clevelandia*, *Cordylanthus*, *Ophiocephalus*, and *Orthocarpus*), has undergone substantial taxonomic revision in recent years (Anderson and Taylor 1983; Chuang and Heckard 1983, 1991, 1992, 1993). *Triphysaria* is most closely allied with *Orthocarpus*, from which it is separated by one, rather than two, anther sacs per stamen, a capitate to bilobed stigma, a corolla upper lip open at the tip, and a base chromosome number of eleven.

The Bearded Owl-clover, *Triphysaria versicolor* Fischer & C. Meyer ssp. *versicolor* (formerly *Orthocarpus faucibarbatu* ssp. *albidus*) is rare in Canada (nomenclature follows Douglas et al., 1991). British Columbia specimens belong to the more widespread of the two subspecies, ssp. *versicolor*. *Triphysaria versicolor* ssp. *versicolor* is 1–5 dm high, with minutely hairy stems and foliage (Figure 1). The leaves are 2–8 cm long, pinnately divided into linear segments, alternately arranged, and well spaced along the stem. Bracts gradually differ from the leaves in color and size. The inflorescence is a terminal spike. Corollas are club-shaped, white fading to pink, the lower lip purple-dotted and hairy

inside. It may be confused with Dwarf Owl-clover (*T. pusilla*) or Thin-leaved Owl-clover (*Orthocarpus tenuifolius*) which also grow in the same habitat in British Columbia. The former has more highly dissected leaves and is a smaller plant, and the latter has narrow, rather than club-shaped corollas.

Distribution

Triphysaria versicolor occurs from northern California (Monterey County) to southern Oregon (Lane County), and disjunctly to south-eastern Vancouver Island, British Columbia. *Triphysaria versicolor* ssp. *versicolor* is the only subspecies of *Triphysaria* found in British Columbia. It is the more widely ranging subspecies of the two; the other, *T. versicolor* ssp. *faucibarbatu*, is restricted to California. In British Columbia, *Triphysaria* is limited to headlands near the ocean on southern Vancouver Island. It is found along approximately 22 km of coastline in the Victoria area from Harling Point to near Glencoe Cove in Gordon Head (Figure 2). British Columbia populations are separated from Oregon populations (Lane County) by a distance of 425 km (Douglas et al. 1991).

Habitat

In British Columbia, *T. versicolor* occurs on open,

*This paper is based on a status report submitted to COSEWIC (Committee on the Status of Endangered Wildlife in Canada) by the authors but formal COSEWIC designation has not yet been made.



FIGURE 1. *Triphysaria versicolor* ssp. *versicolor*, line drawing by Gail Harcombe from Douglas et al. (in press).

grassy headlands near the ocean, no more than 10 m above sea level. The sites are characterized by shallow soils and southern, eastern or north-eastern aspect with slight slope. Micro-sites of this species are vernally damp, and dry up in the summer. *Triphysaria versicolor* grows in dense beds of Camas (*Camassia*), meadows with sparser cover of *Camassia*, and grasses such as Annual Bluegrass (*Poa annua*), Early Hairgrass (*Aira praecox*), Western Fescue (*Festuca occidentalis*), and Brome (*Bromus*) or wetter, and more sparsely-vegetated areas (seeps) with Scouler's Popcornflower (*Plagiobothrys scouleri*). Other associated species include Sea Blush (*Plectritis congestus*), Broad-leaved Shooting Star (*Dodecatheon hendersonii*), Harvest Brodiaea (*Brodiaea coronaria*), Poverty Clover (*Trifolium depauperatum*), and *Triphysaria pusilla*.

In general, *T. versicolor* appears to be tolerant of a relatively wide range of spring moisture condi-

tions. It occurs with *Camassia* spp. in the upper portions of draws, which indicates deeper soils, and relatively lower moisture, and in the lower portions of those draws with *Plagiobothrys scouleri* and Slender Plantain (*Plantago elongata*), which suggests higher moisture (Klinka et al. 1989). Other associates, such as *Festuca occidentalis* and *Aira praecox* are indicators of well-drained soils (Klinka et al. 1989).

General Biology

In British Columbia, seeds of *Triphysaria versicolor* germinate during conditions of elevated moisture in early spring. Flowering occurs by the end of April. By the summer, at which time drought occurs in the Victoria area, sites of this type are very dry and most of the native, annual plants, such as *T. versicolor*, have already flowered and died.

Flowers of *T. versicolor* have short upper lips and larger, saccate lower lips, a flower structure often associated with bee pollination (Chuang and Heckard 1991). In California, pollinators of *T. versicolor* are members of the Short-tongued Bee family, Andrenidae (Chuang and Heckard 1991). However, pollinators for this taxon in British Columbia are presently unknown. All reproduction in *T. versicolor* is likely a result of out-crossing since Thurman (1966) found that the plant was self-incompatible.

Triphysaria versicolor is a root hemiparasite. It is not known precisely what species are being parasitized or to what degree. It is very difficult to match root mats in the soil with the species to which they belong (Kuijt, personal communication). However, associated grasses are likely hosts. In British Columbia, it is not uncommon to find other closely related taxa which are also hemiparasites, such as *Orthocarpus* species or *Triphysaria pusilla*, growing in the same habitat, and likely forming haustorial connections. These mixed-species communities have also been observed in California (Atsatt 1970).

Population Size and Trends

There are eight extant (collected > 1949) populations of *Triphysaria versicolor* on southern Vancouver Island (Table 1). In addition, there is one historic record of this species from the islands south of Victoria. Population size ranges from a few to a thousand individuals (Table 1). There have been no long-term studies of the population dynamics of *T. versicolor* in the Victoria area, thus no information is available on population trends.

Limiting Factors

The growth and survival of *Triphysaria versicolor* is limited by both ecological factors and human disturbance. Populations of *Triphysaria versicolor* in British Columbia are at the northernmost range of the taxon. Peripheral or disjunct populations, which

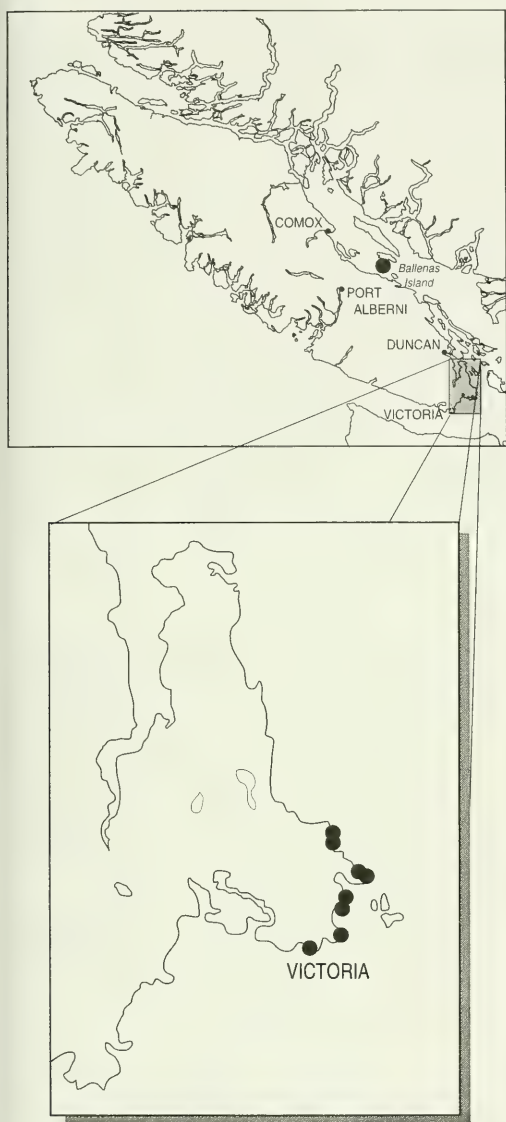


FIGURE 2. Distribution of *Triphysaria versicolor* ssp. *versicolor* in British Columbia.

are far from centers of distribution, may not be in the most suitable conditions for their growth. Only sites within extremely close proximity of the ocean in the shallow soils of rock outcrops appear to provide suitable habitat for *T. versicolor* in British Columbia.

On southern Vancouver Island, human disturbance, especially urban development, seems likely to have a substantial impact. There is extensive public and private waterfront development in the Victoria area, within the range of *T. versicolor*, which may have destroyed populations. Other human-induced threats include habitat alteration on private property,

development within city park localities, and competition from introduced weeds.

Two localities of *T. versicolor* are in parks. One of these is a well-known and frequently visited park, Uplands Park, at Cattle Point in Oak Bay. Uplands Park contains two populations, one in an area of relatively heavy pedestrian traffic, and one on steep rocks where it is less likely to be trampled. Trampling may hamper or enhance the growth of *T. versicolor*. It may reduce the vigor of introduced species such as Ribwort Plantain (*Plantago lanceolata*) or Orchard Grass (*Dactylis glomerata*), or from other native species, and therefore, reduce competition for *Triphysaria versicolor*. This species is fairly common on Cattle Point, and appears not to be threatened by the trampling caused by people visiting the park. However, park development could pose a threat, if planners who are unaware of the locations of the populations were to construct new benches or trails over the populations. Public awareness projects addressing the continued persistence of rare plant populations in regional and city parks are required to protect rare plants such as *T. versicolor*. In some instances on private land, covenants to protect rare plants have been created. However, currently there are no known projects like this in existence in British Columbia provincial parks.

The second park locality is Glencoe Cove, which has only recently been designated a park, and is not yet accessible to the public. Development threats on the oceanfront have been thwarted by local concern. Adjacent areas have succumbed to real estate development, and the buffer zone may be small between them and the rock outcrops. The populations found here have had little disturbance. However, when accessibility is no longer restricted at this site, populations may be threatened.

Another site which is also relatively inaccessible to the public, and which has no housing development nearby, is at the Victoria Golf Club. The population occurs relatively far from the golf course fairways and on fairly steep rocks. Therefore, it is little disturbed by people and development.

Not all sites are completely devastated by development; many private land owners with waterfront property have gardens that completely alter conditions for native plants. Some sites containing populations of *Triphysaria versicolor* may have been destroyed by cultivation of private yards. Lawn grass and cultivated flowering plants have often been planted right to the rocks where suitable habitat for *T. versicolor* may have once existed. Also, yard development has been known to alter the physical characteristics of rock outcrop habitats to the detriment of rare plants. For instance, the moisture regime of the habitat of another rare, early germinant of the Victoria area spring flora, Macoun's Meadowfoam (*Limanthes macounii*) was altered

TABLE 1. Locations and population sizes for *Triphysaria versicolor* ssp. *versicolor* in Victoria, British Columbia.

Population	Last Observation	Collector	Number of Plants/area
Victoria, islands S of	1915	Higgins	unknown
Ten Mile Point, end of Baynes Rd.	1996	Penny	40/5 m ²
Ten Mile Point, end of White Rock Rd.	1996	Penny	21/3 m ²
Cattle Point, S of N boat ramp	1996	Penny	1000/100 m ²
Cattle Point, S of S boat ramp	1996	Penny	415/36 m ²
Victoria Golf Club	1996	Penny	300/30 m ²
Harling Point, Chinese Cemetery	1996	Penny	67/10 m ²
Gordon Head, N of Glencoe Cove, S of Pocket Cove	1996	Penny	1000/0.5 m ²
Gordon Head, N of Glencoe Cove, N of Pocket Cove	1996	Penny	1500/200 m ²

adjacent to a rock outcrop by landscaping (A. Ceska, personal communication). This caused the vernal pools to not receive enough water at the appropriate time, and fewer plants were able to germinate that year. Another possibility is that they may receive too much water at a time when the site is usually drying out, which would encourage weeds to grow there.

Special Significance of the Taxon

Triphysaria versicolor on Vancouver Island is especially interesting because the British Columbia populations represent a range disjunction of over 400 km. It has been suggested that this taxon may have been introduced in British Columbia (Keck 1927). Chuang and Heckard (1991) considered *Triphysaria* to be mainly confined to California, with only *T. pusilla* reaching British Columbia. In this fairly recent work, there was still no reference to *T. versicolor* in British Columbia. The taxon may have been introduced either naturally, for example by a bird, or unnaturally by humans since glaciation.

However, an alternative hypothesis is that on southern Vancouver Island, which was completely glaciated, the populations survived in glacial openings, or dynamic interruptions in the ice. The southern Vancouver Island endemic, *Limnanthes macounii*, exemplifies this theory. On the other hand, the distribution of *Triphysaria versicolor* and others may simply be a result of the geography of the Pacific Northwest coast. Other taxa whose distribution follow a similar pattern to *T. versicolor* are Slim-leaf Onion (*Allium amplexens*) and Small-flowered Tonella (*Tonella tenella*), which occur in the Coastal Douglas-fir zone in south-western British Columbia, Oregon, and California, but are absent from coastal Washington State. In addition, climatic conditions in the Victoria area are similar to the dry intermountain corridor, and much less similar to the wet coastal conditions of most of the coasts of British Columbia and Washington. In view of these climatic factors, a gap like this is not unexpected.

In addition to its interesting distribution, *Triphysaria versicolor* along with its relatives, *Orthocarpus attenuatus* and *Triphysaria pusilla*, have a novel ecological role in the habitat on Vancouver

Island. They are root hemi-parasites of their meadow – rock outcrop associates.

Rock outcrop and vernal seep habitats on south-eastern Vancouver Island themselves also deserve special recognition. They are distinctive ecosystems for British Columbia where other rare plants are also found.

Protection

There is no specific legislation for the protection of rare and endangered vascular plants in British Columbia. The British Columbia Conservation Data Center has ranked this species as S1 and placed it on the Ministry of Environment, Lands, & Parks "Red List," the most critical category for imperiled rare native vascular plants in the province. ("S" ranks, for provincial or state rare elements, are U.S. Nature Conservancy designations. A rank of S1 is defined as follows: "critically imperiled because of extreme rarity with five or fewer extant occurrences or very few remaining individuals or because of some factor[s] making it especially vulnerable to extirpation or extinction" Douglas et al. 1998). Elsewhere in its range, this species is more common.

Four of the eight extant populations are in city parks. These populations are protected from housing developments, but may not be protected from trampling and other activities within the park that occur without knowledge of the existence of the populations. Also, there are no rehabilitation or reintroduction projects known. Therefore, no protection exists for *T. versicolor* in British Columbia.

Evaluation of Status

Triphysaria versicolor is considered an endangered taxon in Canada by the authors and the Conservation Data Centre (Douglas et al. 1998). This species has an extremely restricted range on Vancouver Island, occurring along a stretch of coastline less than 22 km in length. Furthermore, there are only eight known populations of this taxon along that length of shore.

The extensive development of waterfront areas within the range of *T. versicolor*, in Oak Bay, Ten Mile Point, and Gordon Head leaves little undis-

turbed habitat left for the plant to potentially colonize. The populations in city parks are subject to heavy pedestrian traffic and may be threatened by development within the park. There are no covenants protecting rare plant populations in Victoria parks. Therefore, all of the sites are potentially imperiled.

In British Columbia, only the general distribution, ecology, and biology of *Triphysaria versicolor*, and other rare plants, are known but no specific details about them. For instance, the phenology, pollinators, and self-pollination breeding systems of *T. versicolor* populations are not well understood. In addition, a study on genetic variability, especially between the British Columbia, Oregon, and California populations, would provide some insight into this species over its entire range. Furthermore, there have been no studies done on *T. versicolor* in British Columbia, except some cytological work on the haustoria, or the connections between host and hemi-parasite (Heide-Jorgensen and Kuijt 1995); it would be of great interest to match haustoria, and determine host specificity.

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Movements and Activity of Caribou, *Rangifer tarandus caribou*, of the Torngat Mountains, Northern Labrador and Québec

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We used satellite telemetry to study the movements, space use, and activity patterns of adult female Woodland Caribou (*Rangifer tarandus caribou*) of the Torngat Mountains in northern Labrador and Québec. These Caribou exhibited seasonal cycles of activity with highest levels during summer (late June to late September) and lowest levels during pre-calving and calving (early May to late June). Caribou were migratory. In most instances, during calving and summer they resided in the vicinity of the Torngat Mountains; during autumn, they moved west into the forest-tundra of the western drainage of the Mountains; during winter, Caribou remained along the coastal plain of eastern Ungava Bay, or, in some cases, along the Labrador coast. Our results confirm that Torngat Mountain Caribou, although occasionally intermingling with the larger George River herd, represent a population spatially distinct from others in the Ungava.

Key Words: Caribou, *Rangifer tarandus caribou*, activity, movements, population, space-use, Labrador, Quebec.

In northern Labrador and Québec, several populations of Woodland Caribou (*Rangifer tarandus caribou*) have been identified and studied (e.g., Brown et al. 1986; Couturier et al. 1990, 1996). These distinct Caribou herds, distinguished by their use of traditional calving grounds or fidelity to individual calving sites, represent two common ecotypic designations of *Rangifer*: the migratory ecotype, which undertakes extensive movements and aggregates at calving, and the sedentary ecotype, which displays more limited movements and dispersion at calving (Bergerud 1988). Incidental reports from residents of the Ungava have indicated that another population, known locally as “Koroc River” or “Torngat Mountain” Caribou, resides in the northeastern portion of the Québec-Labrador Peninsula (Figure 1). For the management of wildlife, the identification of populations is essential (e.g., Bethke et al. 1996), but the habits of Torngat Mountain Caribou are yet to be described in the literature.

From 1988 to 1997, we used satellite telemetry to study Caribou from the Torngat Mountains and vicinity. We examined seasonal patterns of activity, space use, and movements of six adult females. Here, we report the results of this monitoring and discuss the extent to which Torngat Mountain Caribou might be considered as population distinct from other herds of northern Québec-Labrador.

Study Area

A prominent feature of the area (Figure 1) was the Torngat Mountains, the highest elevations in eastern North America (1428 m). The topography was domi-

nated in the east by plateaus (200 - 1400 m) dissected by numerous fiords and broad U-shaped valleys, and in the north and west, by rugged foothills gradually descending to low coastal plains (<200 m asl). Most of the study area was, by virtue of latitude or altitude, above tree line. Meades (1990) classified the eastern portion as consisting of low arctic tundra, low arctic alpine, and high subarctic tundra. Progressing northward, vegetation at low elevations ranged from closed spruce (*Picea* spp.) forests in the drainage of Okak Bay, to thickets of alder (*Alnus* spp.) and willow (*Salix* spp.) to moss heaths and snowbed communities along coastal plains. In higher elevations, rock beds and alpine heaths were characteristic. Mean February and July temperatures were -21°C and 7°C, respectively, with precipitation about 600 mm per year (Meades 1990).

Permanent human settlements were represented by the communities of Kangiqsualujjuaq and Kuujuaq in the southwestern segment of the study area. The community of Hebron, on the Labrador coast near Hebron (Kangerdluksoak) Fiord, was abandoned in 1959, and Port Burwell, at the extreme northern tip of the Torngat Mountains Peninsula was abandoned in the late 1970s. Exploitation of natural resources was generally light, and comprised hunting, trapping, fishing, and mineral exploration. Hunting of Caribou was carried out by residents of northern Labrador and Ungava Bay, and a commercial Caribou harvest was initiated from Kangiqsualujjuaq during the winter of 1995-96 (S. Couturier, personal communication).

Most of the the study area constituted a portion of the range of the George River Caribou (*R. t. caribou*)

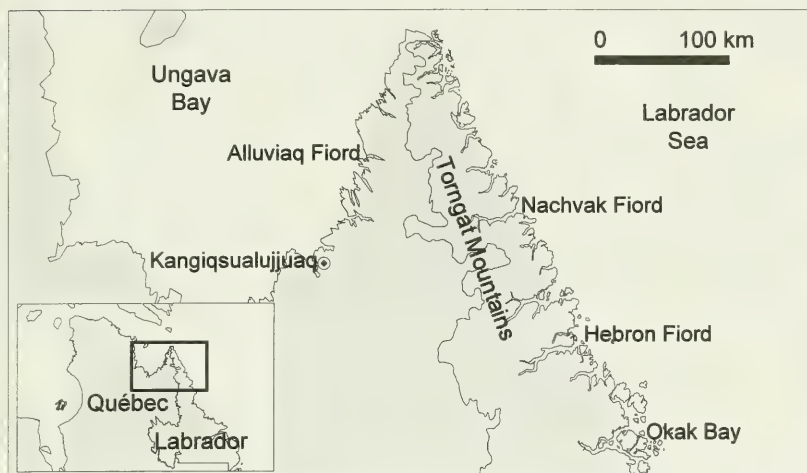


FIGURE 1. Study area for Torngat Mountain Caribou in the northeastern Québec-Labrador Peninsula.

herd, at 600 000 to 800 000 animals, the largest Caribou population in the world (Couturier et al. 1996). Many George River Caribou frequented the study area during summer (Newfoundland-Labrador Wildlife Division, unpublished data). The traditional calving grounds of this herd were located in the southwestern portion of the study area, generally south of Kangiqsualujuaq and west of Kangerdluksoak (Hebron) Fiord (Couturier et al. 1990; Figure 1).

Methods

We conducted the study from 9 November 1988 to 16 August 1997. We captured adult (>2 year old) female Caribou using chemical restraint agents, administered by darts fired from a helicopter, and deployed satellite-tracked (Service Argos, Landover, Maryland) ultra high frequency Platform Terminal Transmitters (PTTs; Telonics, Mesa, Arizona). PTTs had 3-day or 4-day transmission cycles and were equipped with 24-hour activity sensors. We replaced or removed PTTs prior to battery exhaustion. One mortality occurred within 30 days after capture and was judged to be caused by the capture itself; these data were not included in the analysis. We maintained one to three active collars throughout the study. In total, we tracked the movements and activity of six adult females for an average of 2.6 years each (range: 0.54 - 5.93 years).

For the analysis of the satellite telemetry data, we first selected the PTT location during each transmission period with the best quality class (i.e., NQ; Keating et al. 1991) as provided by Service Argos. We discarded locations with NQ < 1 due to their inherent imprecision (Keating et al. 1991). To the remaining data, we applied Keating's ξ , a statistic indicating potentially erroneous locations, deter-

mined by successive vectors of animal movement (Keating 1994). We tentatively deemed the upper 5% of ξ values as erroneous. Following Rettie and Messier (1998), we retained such locations only if each could be confirmed by another, independent location within the same transmission period; otherwise, the location was discarded and replaced with another location during this period, subject to the same criteria. In total, we retained 1245 locations on the six study animals. The number of locations per animal ranged from 23 to 495.

To help distinguish temporal patterns of activity, we used the data from 24-hour activity sensors as an index of activity. These data were centered and standardised by PTT (i.e., mean = 0 and SD = 1) to allow for comparisons between animals. We calculated the mean activity index for each 4-day period throughout the calendar year using the individual Caribou as the sampling unit. Using the activity patterns supplemented with occasional, direct observations of Torngat Mountain Caribou, we identified six periods during the Caribou annual cycle: winter (16 November to 2 May), pre-calving (3 May to 4 June), calving (5 June to 25 June), summer (26 June to 25 September), fall (26 September to 14 October), and breeding (15 October to 15 November).

We tested for differences amongst these seasons in travel rates and activity levels among seasons. Because speed of individual Caribou may be scale-dependent (i.e., contingent on the time between relocations), we conducted separate analyses on speed as measured by 3-day and 4-day transmission cycles. For each variable, we used a mixed-model ANOVA (SAS Institute Inc., 1990) with season and animal as treatment and blocking factors, respectively. We applied the Tukey procedure to examine differences between individual seasons. To minimise the number

of missing cells in the analysis, we used only those animals ($n = 4$) which had observations during at least four seasonal periods.

Results

Caribou exhibited seasonal cycles of activity. From the PTT sensors, at least two distinct periods of activity could be discerned (Figure 2): a period of comparatively low activity during pre-calving and calving, followed by an abrupt transition to high activity during summer. During the remainder of the year, there was considerable fluctuation, and, at least with our modest sample size, no prominent patterns could be detected (Figure 2). Indeed, although there was significant variation in activity levels amongst seasons ($F_{5,13} = 4.24$, $p = 0.015$), substantial differences existed only between summer and the calving and pre-calving periods (Tukey HSD = 0.742). Rates of movement by Caribou were variable and not different amongst seasons, measured on both 3-day ($F_{5,5} = 3.66$, $p = 0.090$) and 4-day transmission cycles ($F_{5,13} = 1.48$, $p = 0.263$). Despite the lack of statistical significance, the mean seasonal speeds were broadly consistent with levels of activity; Caribou exhibited rates of travel which were highest

in summer, fall, and breeding (about 4.0 km/day), lowest during pre-calving and calving (about 1.8 km/day), and intermediate in winter (about 2.2 km/day).

In general, Caribou were resident throughout their annual cycle east of Ungava Bay and north of Okak Bay (Figure 3); 89.2% of locations occurred thin this area. Two study animals emigrated temporarily (>250 km) and were associated with Caribou of the George River Herd (Schaefer and Lutich, unpublished data). One emigrant returned to Tornat Mountain Caribou range after overwintering approximately 200 km south of Okak Bay; the other returned after about 2 years of residency on George River range.

Tornat Mountain Caribou were migratory (Figure 3, 4). In general, study animals resided along the coastal plain of eastern Ungava Bay during fall, breeding, and winter, and moved to the vicinity of the Tornat Mountains during pre-calving and calving (Figure 4). Our direct observations of calving locations were few. Nevertheless, the positions of PTTs during this period (4 - 25 June) suggested that most calving activity was encompassed by a broad area of tundra and rock barrens across the eastern half of the study area, south to include the watershed of Hebron

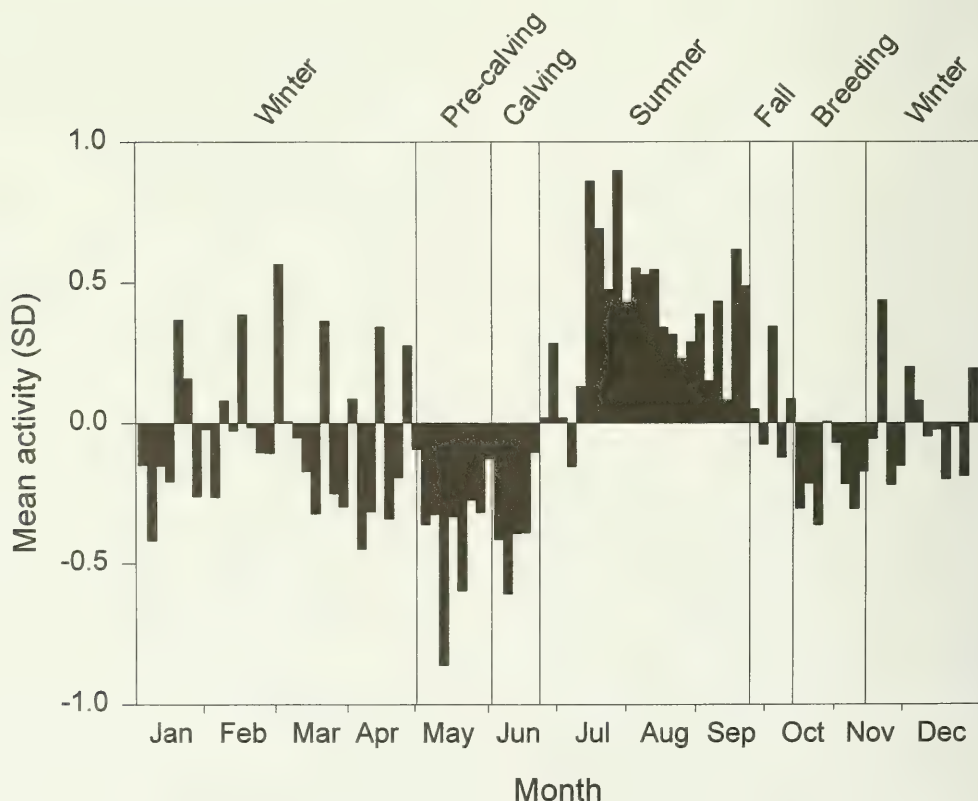


FIGURE 2. Mean activity levels of adult female Tornat Mountain Caribou, 1988-1997, as determined by satellite telemetry. Units are expressed in standard deviations (SD).

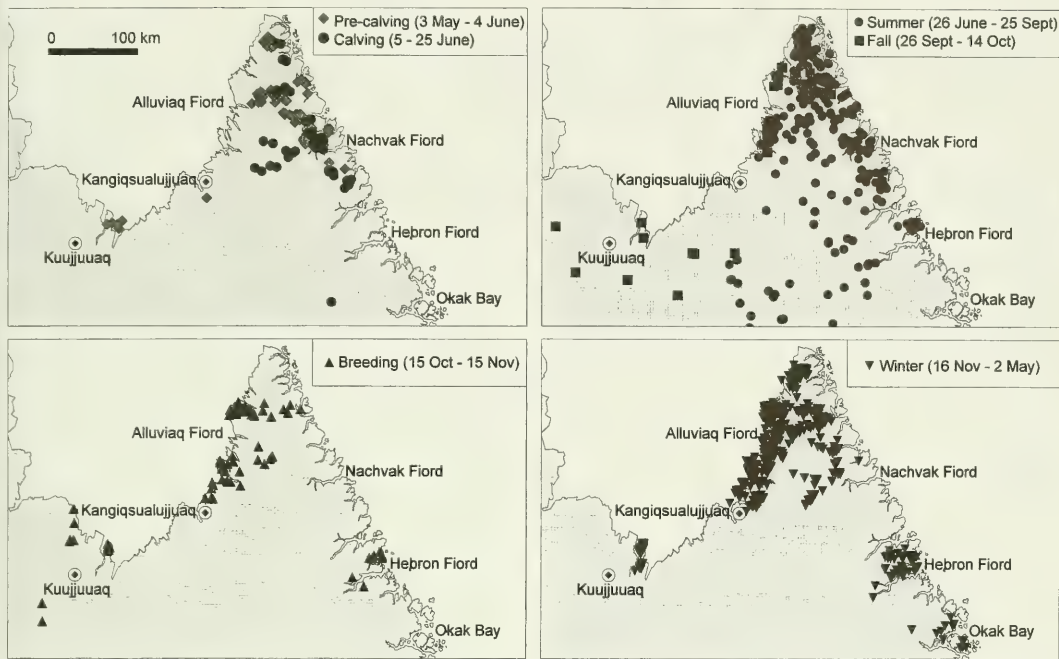


FIGURE 3. Seasonal ranges of adult female Torngat Mountain Caribou, 1988-1997.

Fiord (Figure 3). In addition, one animal resided in the drainage of Okak Bay at least during the latter part of this period. Post-calving aggregations occurred along the eastern drainage of the Torngat Mountains, an area also frequented by George River Caribou during this time (Figure 3). The aggregate distribution of Torngat Mountain Caribou was more

expansive during summer, consistent with the high rates of movement during this time of year.

Areas of fall and wintering activity were variable (Figure 3). In addition to eastern Ungava Bay, study animals occasionally overwintered near Hebron Fiord or Okak Bay along the Labrador coast, or along the southern portion of Ungava Bay near

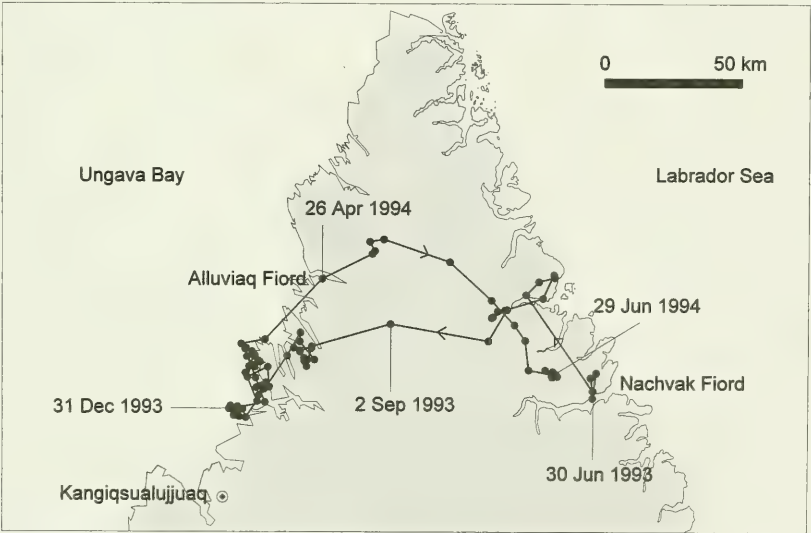


FIGURE 4. Typical annual migration pattern of an adult female Torngat Mountain Caribou.

Kuujuuaq (Figure 3). The total annual distance travelled by Caribou, excluding periods of egress, averaged 753 km (SE = 49 km, $n = 3$), based on 4-day transmission intervals and 690 km ($n = 1$) based on a 3-day transmission interval.

Discussion

The activity of Torngat Mountain Caribou (i.e., exhibiting a nadir in late spring [pre-calving and calving] followed by a peak in summer [post-calving]) is in broad agreement with direct, year-round observations of *Rangifer* from other populations. For example, in Alaska, Boertje (1985) reported comparable seasonal extremes: the proportion of time spent lying peaked at calving time and ebbed during the ensuing "insect season". Similarly, Roby (1978, in Klein 1992) indicated that daily foraging time reached a minimum during calving. Satellite telemetry appears to provide an accurate portrayal of the broad classes of behaviour by ungulates, particularly activity from non-activity (Fancy et al. 1988; Hansen et al. 1992). In our study, we suspect that the absence of other prominent seasonal periods (Figure 2) may stem from our small sample size.

The identification of populations (i.e., natural groupings of organisms, defined primarily by spatial discontinuities; Wells and Richmond 1995) is integral to our understanding and management of living resources (e.g., Taylor and Lee 1995; Bethke et al. 1996). Our results demonstrate that patterns of space use by Torngat Mountain Caribou were largely distinct from those of the George River Herd (Couturier et al. 1990; Newfoundland-Labrador Wildlife Division, unpublished data). While these two herds exhibited overlapping post-calving aggregations near the Labrador coast, they maintained mutually exclusive ranges during other points in their annual cycle, including calving, breeding, and overwintering. Traditional calving ranges, in particular, have been viewed by biologists as useful designations of herd identity (Skoog 1968; Gunn and Miller 1986). Despite temporary egress of some Torngat Mountain Caribou, our findings underline the spatial discreteness of this group from other herds in the Ungava (Brown et al. 1986; Couturier et al. 1990). As such, Torngat Mountain Caribou appear to constitute a distinct population (Wells and Richmond 1995).

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Status of the Yellow Montane Violet, *Viola praemorsa* ssp. *praemorsa* (Violaceae) in Canada*

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Douglas, George W., and Michael Ryan. 1998. Status of the Yellow Montane Violet, *Viola praemorsa* ssp. *praemorsa* (Violaceae) in Canada. *Canadian Field-Naturalist* 112(3): 491–495.

In Canada, *Viola praemorsa* ssp. *praemorsa* is restricted to *Quercus garryana* stands and grass-dominated meadows on southeastern Vancouver Island and Saltspring Island. Eight sites have been confirmed in recent years but the status of plants at five other sites remains uncertain. It is likely that the violet has been extirpated in at least one of these sites. These Canadian sites represent the northern range limits of *Viola praemorsa* ssp. *praemorsa* at the species and subspecies levels. Threats to existing populations vary in intensity. Although most populations are protected to a certain extent from direct habitat destruction, introduced species pose a serious potential threat to the continued existence of most populations. Unfortunately, managing sites for *V. praemorsa* ssp. *praemorsa* is difficult because so little information is available regarding the general biology of this species.

Key Words: Yellow Montane Violet, *Viola praemorsa* ssp. *praemorsa*, threatened, distribution, population size. British Columbia.

The Yellow Montane Violet, *Viola praemorsa* Dougl. ex Lindl. ssp. *praemorsa*, is a member of a genus of about 300 species, occurring throughout much of the world (Hitchcock and Cronquist 1961). It is one of 22 species occurring in British Columbia (Packer 1991) and about 38 occurring in Canada (Scoggan 1979). *Viola praemorsa* ssp. *praemorsa* is not known to have any medicinal or economic uses.

Viola praemorsa belongs to subsection *Nuttallianae* which has been a source of difficulty to researchers because it is composed of a polyploid complex of intergrading morphologically similar species. Some workers consider *Viola praemorsa* to be a subspecies or variety of *Viola nuttallii* (Hitchcock and Cronquist 1961; Scoggan 1979). However, those who have intensively studied this polyploid complex (Baker 1957; Clausen 1964; Fabijan et al. 1987; Packer 1991) consider *V. praemorsa* to be a distinct species composed of several subspecies. The most recent investigation of this group was based on morphological, cytological, and phytochemical data which were used in numerical and statistical analyses to distinguish between species, subspecies and varieties (Fabijan et al. 1987). They concluded that *V. praemorsa* encompasses a wide range of chemical and morphological characteristics of which the extremes characterize three subspecies.

Viola praemorsa ssp. *praemorsa* is a perennial from a short, erect rootstock, ranging from 6 to 25 cm tall with broadly lanceolate, conspicuously hairy or rarely nearly glabrous, mainly basal leaves with blades to 2 to 10 cm long (Figure 1). The yellow, terminal flowers are solitary on one to several, erect stems.

Distribution

Viola praemorsa ssp. *praemorsa* occurs on the west coast of North America from southwestern British Columbia to northern California (Hitchcock and Cronquist 1961). In Canada, it is restricted to southeastern Vancouver Island and adjacent Saltspring Island (Figure 2).

Habitat

In British Columbia, *Viola praemorsa* ssp. *praemorsa* occupies a number of different habitats in Garry Oak (*Quercus garryana*) communities and grass-dominated meadows. The *Quercus garryana* community within which *Viola praemorsa* ssp. *praemorsa* occurs predominantly occurs on deeper soils with less exposed bedrock (Figure 3). These sites also contain a substantial number of forbs including White Triteleia (*Triteleia hyacinthina*) and Western Buttercup (*Ranunculus occidentalis*) but tend to be dominated by a mixture of introduced grasses such

*This paper is based primarily on a COSEWIC status report by the authors. It has been revised to include more recent information. The species was designated threatened by COSEWIC in April 1996. Original reports are available from the COSEWIC Secretariat, c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada.

as Early Hairgrass (*Aira praecox*), Orchardgrass (*Dactylis glomerata*), Hedgehog Dogtail (*Cynosurus echinatus*) and Sweet Vernalgrass (*Anthoxanthum odoratum*), and several species of *Bromus*. Some stands are dominated in the understorey by shrubs, in particular, Snowberry (*Symphoricarpos albus*) and Scotch Broom (*Cytisus scoparius*), which effectively shade out many herbaceous species. Soils are usually orthic sombric brunisols (Roemer 1972).

Some populations have also been located on relatively steep rocky slopes where *Quercus garryana*-*Holodiscus discolor* (Ocean Spray) is the dominant vegetation type. On these sites they are usually located in pockets of deep soil partially shaded by *Quercus garryana*. *Viola praemorsa* ssp. *praemorsa* may occasionally be found in open grass-dominated meadows where soils are relatively deep and likely retain some moisture during summer drought conditions.

General Biology

Viola praemorsa ssp. *praemorsa* is a perennial species which overwinters as a short vertical rhizome. In British Columbia, *V. praemorsa* ssp. *praemorsa*, as with many other forbs located in *Quercus garryana* communities, appears to take advantage of the warm temperatures, ample moisture, and high light levels found during spring. In early spring (March) the leaves emerge, followed by the appearance of flowers in April and May. This usually occurs before the *Quercus garryana* leaves have fully emerged and before grasses, which usually dominate the understorey, have grown to a sufficient size where they shade or smother *Viola praemorsa* and other forbs. Seeds are explosively ejected from the capsules during early to mid-summer and most plants then die back to the perennating rhizome. Some plants retain their leaves and produce elongated decumbent stems which may exceed 25 cm in length. Eventually these plants will also wither and die back to the perennating rhizome.

Viola praemorsa does not appear to spread by either stolons or rhizomes, hence, seed production appears to be very important in the maintenance and spread of this species into new habitats. Unfortunately, there is little direct information on the importance of insect pollinators, the proportion of flowers that are self- and cross-pollinated, and the average number of viable seeds produced by individual plants. In a discussion of the floral structure of *V. praemorsa*, Baker (1935) states that the style and stigma are pressed closely to the groove formed by the lower petal and produces such a close fit that a small insect cannot force an entrance underneath or on either side of the style and must crawl over the stigma to reach the stamens and nectaries. On many occasions he observed thrips crawling along the



FIGURE 1. Illustration of *Viola praemorsa* ssp. *praemorsa*. (Line drawing by Lora-May Richards in Douglas et al. [1998]).

groove formed by the lower petal until they were stopped by the close fitting head of the style. To reach the pollen and nectaries, the thrips were required to crawl over the stigma before they could reach the pollen behind the broad appendages connected to the stamens. Hence, because the order in which insects contact the floral structures are stigma, stamens, and nectaries, pollen deposited on the stigma is likely to have come from another flower thus favouring the likelihood of cross-pollination. Further evidence suggesting that cross-pollination is common in *Viola* is provided by Beattie (1969). He found that when insects were excluded from 30 flowers, only two of the flowers showed signs of ovule development which suggests that self-pollination is an uncommon event. Alternatively, when the stamens of 30 flowers were removed but not excluded from contact with insects, 27 of the flowers showed ovule development suggesting these flowers were pollinated by pollen transported from other flowers.

Like other *Viola* species, *V. praemorsa* ssp. *praemorsa* may also produce seeds by cleistogamous flowers. These are flowers that contain both stamens

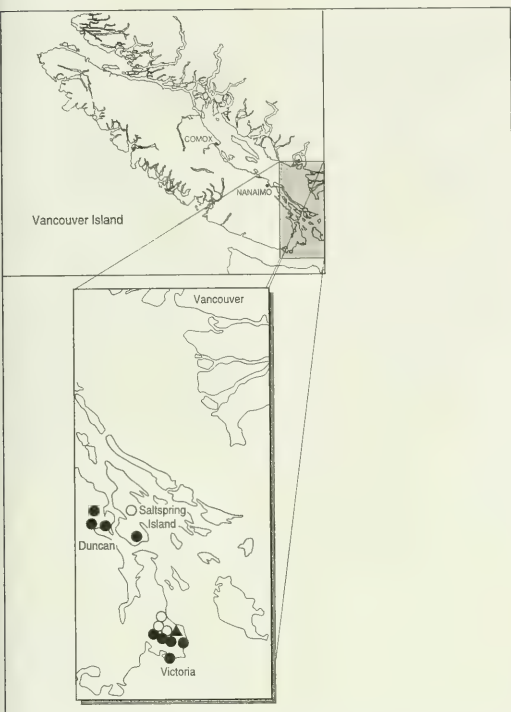


FIGURE 2. Distribution of *Viola praemorsa* ssp. *praemorsa* in British Columbia. (▲ - extirpated sites, ○ - unconfirmed sites, ● - recently confirmed sites)

and ovules which do not open but produce seeds by self-pollination. They emerge after the petaliferous flowers have completed flowering. The extent to which *V. praemorsa* produces cleistogamous flowers and the importance of their contribution to seed production is not known.

Population Size and Trends

Viola praemorsa ssp. *praemorsa* has been collected or observed at 13 sites in Canada with all of these populations located in British Columbia on southeastern Vancouver Island or adjacent Salt Spring Island (Table 1). Five of these sites remain unconfirmed with plants at one of these probably extirpated. Eight sites were resurveyed or discovered during the present study. Population areas range from very small (one m²) to over 5000 m² in size (Table 1). Individual numbers of plants ranged in the hundreds for most sites with higher counts (in the thousands) being recorded for the Somenos Lake and Quamichan Lake sites (Table 1).

Populations at six of the sites (Beacon Hill, Falaise Park, Mount Tzuhalem, Quamichan Lake, Somenos Lake and Uplands Park) have been observed with respect to populations trends. During a four-year time period the latter populations main-

tained their size and plant numbers within 10% of their maximums.

Limiting Factors

The most direct and immediate threat to *Viola praemorsa* ssp. *praemorsa* is habitat destruction. This is of particular concern in the grass-dominated meadows often associated with the *Quercus garryana* communities that are limited to the southeastern side of Vancouver Island and some of the Gulf Islands. Both types of vegetation are believed to have been much more common before colonization by European settlers. Their destruction has continued to the present resulting in the elimination of almost all sites occurring outside parks or ecological reserves. Historically, *Quercus garryana* communities and grass-dominated meadows have always been heavily influenced by human activity. Roemer (1972) believed that without human interference some of these stands would have eventually been replaced by Douglas-fir, *Pseudotsuga menziesii*, forests.

The suppression of fire within the past century may also have contributed to the decrease of *Viola praemorsa* ssp. *praemorsa* populations. Most of the sites in which *V. praemorsa* ssp. *praemorsa* has been collected were likely maintained in the past as a result of periodic fires, both natural and unnatural. In the past, aboriginal peoples probably set fire to these stands to maintain them as an important habitat for wildlife (Roemer 1972). Since that time, these sites have experienced little disturbance, resulting in the invasion and expansion of many other species, especially introductions.

The introduction of European species has resulted in substantial changes, not only to the grass-dominated meadows associated with *Quercus garryana*, but also to the rocky xeric sites north and west of



FIGURE 3. A *Quercus garryana* stand at Quamichan Lake, British Columbia. *Viola praemorsa* ssp. *praemorsa* is a prominent species in the understory of this stand.

TABLE 1. Populations of *Viola praemorsa* ssp. *praemorsa* in Canada.

Collection Site	Last Observation	Collector/ Observer	Population (no./area)
Cedar Hill (Victoria)	1887	Macoun	Extirpated
Holmes Point (Comox)	1961	Beamish	Unconfirmed
Mount Tolmie (Victoria)	1963	Young	Unconfirmed
Christmas Hill (Victoria)	1971	Roemer	Unconfirmed
Nanoose Hill (Nanaimo)	1976	Douglas	Unconfirmed
Mount Tuam (Salt Spring Island)	1995	Chatwin	300+/400 m ²
Beacon Hill (Victoria)	1997	Douglas	465/1000 m ²
Smith Hill (Victoria)	1997	Douglas	490/435 m ²
Uplands Park (Victoria)	1997	Douglas	95/18 m ²
Mount Tzuhalem (Duncan)	1997	Douglas	56/120 m ²
Somenos Lake (Duncan)	1997	Douglas	45,000+/5700 m ²
Quamichan Lake (Duncan)	1997	Douglas	6400+/1000 m ²
Falaise Park (Victoria)	1997	Douglas	59/10 m ²

Victoria where *Viola praemorsa* ssp. *praemorsa* has been collected in the past. One of the most devastating species is *Cytisus scoparius* which has become a dominant shrub on xeric, exposed sites throughout much of southeastern Vancouver Island and the Gulf Islands. Much of the vegetation is now dominated by introduced grasses. These species include *Aira praecox*, *Anthoxanthum odoratum*, *Cynosurus echinatus* and *Dactylis glomerata*.

Special Significance of the Species

Viola praemorsa ssp. *praemorsa* is a member of a relatively small group of species with a restricted Pacific Coast range that have their northern limits in southern British Columbia. The significance of these peripheral populations, especially with respect to their genetic characteristics, has yet to be studied adequately. This species may prove to be a fruitful subject for genetic research.

Protection

There is no specific legislation for the protection of rare and endangered vascular plants in British Columbia. The British Columbia Conservation Data Centre has ranked this species as S2 and placed it on the Ministry of Environment, Lands and Parks Red list. S ranks, for provincial or state rare elements, are those of The U.S. Nature Conservancy. A rank of S2 is defined as "imperiled because of rarity (typically 6-20 extant occurrences or few remaining individuals) or because of some factor(s) making it vulnerable to extirpation or extinction". This Red list classification is the most critical category for imperiled rare native vascular plants in the province (Douglas et al. 1998).

Some populations of *Viola praemorsa* ssp. *praemorsa* are partially protected by their location in municipal parks or provincial ecological reserves. Of all the *V. praemorsa* ssp. *praemorsa* sites known in

British Columbia, the ones at Mount Tzuhalem and Mount Maxwell receive the greatest degree of protection because of their location within ecological reserves. The Mount Tzuhalem Ecological Reserve encompasses 18 ha of *Quercus garryana* woodland, spring-flowering meadows, and rock outcrops that have been preserved to represent an example of *Q. garryana* woodlands and associated spring-flowering herbs. The Mount Maxwell Ecological Reserve is 65 ha in size and includes habitat similar to that at Mount Tzuhalem. A number of *Viola praemorsa* ssp. *praemorsa* populations are in small regional parks in the Greater Victoria area. These include populations at Beacon Hill, Falaise, Royal Oak, Smith Hill, and Uplands Park. These parks receive little active management, at least with respect to their rare plants. Park enhancement projects, road and trail developments and heavy recreational use by humans often result in the destruction of the native vegetation and rare plant species.

The two largest populations are on private property in the Duncan area. The largest population in British Columbia is part of a large subdivision near Somenos Lake and a portion of the site will probably be set aside as a small park. The close proximity of housing and increased foot traffic in the area may have an adverse effect on the native vegetation. A second property in the area, near Quamichan Lake, is presently under consideration for housing development and, in this case, lots may be created within the *Quercus garryana* community thus destroying the *Viola praemorsa* populations.

Evaluation of Status

Viola praemorsa ssp. *praemorsa* is considered, by COSEWIC and the British Columbia Conservation Data Centre, to be threatened in Canada and is known only from 12 extant sites restricted to southeastern Vancouver Island and adjacent Salt Spring

Island. Some populations are limited to less than a few hundred individuals and may be in danger of extirpation. The prognosis for this species is not good considering the threats posed by aggressive competitive species such as *Cytisus scoparius* which dominate many suitable habitats and directly threaten some populations. Therefore, even if all sites were protected from human interference, many populations may eventually disappear as a result of aggressive competitive species. Likewise, much of the *Quercus garryana* vegetation in which *Viola praemorsa* is usually found has been extensively altered or destroyed, thus limiting the potential of this species to become established at new sites.

Acknowledgements

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Observations on the Ecology of the Lichen Genus *Bryoria* in High Elevation Conifer Forests

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The distributional ecology of the tree-dwelling "hair lichens" *Bryoria fremontii* and *B. pseudofuscescens* is examined, based on observations in high elevation conifer forests of inland British Columbia. Seven obvious microscale and mesoscale patterns are reported for one or both of these species: (1) a failure to successfully colonize branches occurring below the upper limit of the winter snowpack; (2) an occurrence in much lower abundance over the outer, foliated portions of branches than over the inner, defoliated portions of the same branches; (3) a tendency to periodic die-off in the outer, foliated branches, but not in the inner, defoliated branches; (4) a development of disproportionately heavier loadings over old, senescent trees than over young, vigorously growing trees of similar size; (5) an ability to colonize all levels of the forest canopy, including the upper crowns of trees; (6) an anomalously higher biomass in young stands growing in exposed sites than in young stands growing in sheltered sites; and (7) a development of considerable biomass in poorly illuminated stands that are nevertheless well ventilated. Based on these observations, the main distributional features of these species, and of *Bryoria* as a whole, are assumed to reflect a pronounced sensitivity to prolonged wetting, especially as a result of snowmelt. Other environmental factors are apparently less important, at least in the study area.

Key Words: *Bryoria fremontii*, *Bryoria pseudofuscescens*, arboreal lichens, conifer forests, British Columbia.

Few lichens are more familiar to biologists than *Alectoria*: an assemblage of hair-like species adapted especially to inhabiting the trunks and branches of conifers. Traditionally, *Alectoria* has been interpreted as a large "form genus" encompassing a majority of tree-dwelling "hair lichens". More recently, however, Brodo and Hawksworth (1977) and Common and Brodo (1995) have shown that the brownish and blackish species are not closely related to the greenish species, and should be assigned to various segregate genera, including *Bryoria*. The name *Alectoria* is thus currently reserved for a small assemblage of greenish hair lichens that contain usnic acid. Whatever their circumscription, these lichens are widespread and common in Canada's northern boreal woodlands, and are abundant also in the montane forests of British Columbia. In the latter region, they provide an important winter food for various ungulates, especially including the Woodland Caribou (*Rangifer tarandus caribou*) (Edwards and Ritcey 1960; Antifeaux 1987). Not surprisingly, *Alectoria* and *Bryoria* are of considerable interest to wildlife biologists.

It is now generally accepted among lichenologists that some lichen species are associated predominantly, or even exclusively, with late successional or old-growth forests (e.g., Rose 1976, 1992; Tibell 1992; Neitlich 1993; Goward 1994; Selva 1994). Though few physiological data are available to account for this phenomenon, oldgrowth dependency is usually assumed to be a function of various attributes pecu-

liar to oldgrowth ecosystems. Such attributes might include, for example, humid microclimatic conditions, availability of bark and wood in various stages of soundness and decay, relative environmental stability, and the existence of microsites not available in younger forest ecosystems.

An unusual form of "oldgrowth dependency" is exhibited in the high elevation conifer forests of northwestern North America by *Alectoria* and *Bryoria*. Though most species belonging to these genera colonize at a rather early phase in forest succession, they usually do not achieve appreciable biomass until much later (Lesica et al. 1991; McCune 1993; Esseen and Renhorn 1996). By the time a forest has attained oldgrowth status, hair lichen biomass may be truly spectacular, with loadings of more than 3000 kg per hectare having been recorded in southern inland British Columbia (Edwards et al. 1960). Such loadings are apparently unequalled in other parts of the world (Rhoades 1995).

During the past four decades, considerable work has been undertaken on the ecological behaviour of *Alectoria* and *Bryoria* in the high elevation forests of southern inland British Columbia and adjacent Idaho (e.g., Edwards et al. 1960; Ahti 1962*; Stevenson 1979, 1990; Antifeau 1987; Rominger et al. 1994). Most of this work has been performed by wildlife

*See Documents Cited section.

Most of this work has been performed by wildlife biologists, and all of it has been prompted by concern for the welfare of this region's Woodland Caribou. In part because these animals depend on the availability of large quantities of hair lichens, Caribou populations in southern British Columbia tend to be adversely affected by the loss of old-growth forests through logging and other agents of disturbance (for further discussion, see Stevenson and Hatler 1985).

Eleven hair lichens have been reported from British Columbia's high elevation inland conifer forests (see for example Goward and Ahti 1992). However, only three of these species — *Alectoria sarmentosa* (Ach.) Ach., *Bryoria fremontii* (Tuck.) Brodo & D. Hawksw. and *B. pseudofuscens* (Gyelnik) Brodo & D. Hawksw. — may be said to contribute significantly to total hair lichen biomass; most of the remaining species occur in much lesser abundance. Given, however, that the combined ecological amplitude of these three species more or less embraces that of hair lichens as a whole in these forests, considerable insight may be gained through a study of their microscale and mesoscale distributions.

In recent years, the British Columbia forest industry has attempted to mitigate the impacts of logging on Caribou by designing silvicultural prescriptions intended to accelerate the development of hair lichen loadings. Unfortunately, most of the work conducted to date appears to have been performed in the absence of a general hypothesis on the distributional ecology of these lichens. The purpose of the present paper is to propose such a hypothesis for the genus *Bryoria*, based on the behaviour of *B. fremontii* and *B. pseudofuscens*. It is hoped the ideas expressed here may help to direct future quantitative studies on hair lichens and, not less, to guide future forest management practices within the range of British Columbia's Woodland Caribou. A future paper will discuss the distributional ecology of *Alectoria sarmentosa* (Goward, in preparation).

Ecological observations on hair lichens, including *Bryoria*, are notoriously resistant to precise quantification: first owing to their occurrence over trees: a three-dimensional habitat (McCune 1990; Stevenson and Enns 1993); second owing to their three-dimensional growth form (Goward and Arsenault 1997); and third owing to their tendency to reproduce through fragmentation (Brodo and Hawksworth 1977). Because fragments of *Bryoria* are regularly distributed throughout the forest canopy by wind or other agents of dispersal, detailed quantitative studies — including studies of biomass, microclimate, and physiological response — cannot be relied upon to convey ecologically unambiguous information. In response to these difficulties, and in the belief that careful observation has much to teach about lichen

ecology, the methods adopted in the present study are largely qualitative. They especially involve the detection of obvious microscale and mesoscale distributional patterns in *Bryoria*.

The observations reported here are based on incidental field studies carried out over a period of five years in southern inland British Columbia, especially in the Sicamous Creek Research Forest (50°49'N, 118°50'W: Hollstedt and Vyse 1997) and in Wells Gray Provincial Park (51°51'N, 119°52'W: Goward and Ahti 1992). The forests under study occur at an elevation between 1450 m and 2100 m, and are dominated by *Abies lasiocarpa* and *Picea engelmannii*; they belong to the Engelmann Spruce - Subalpine Fir Biogeoclimatic Zone (hereafter "ESSF") of Meidinger and Pojar (1991), as well as to the Upper Oroboreal and Orohemiarctic Subzones of Tuhkanen (1984; see also Goward and Ahti 1992). Climatic conditions are cold and humid. Mean monthly temperatures exceed 10°C during only one or two months of the year, and snow covers the ground during seven to eight months of the year. In the lower portions of the ESSF, the forest canopy is more or less continuous, and the understory tends to be dominated by various shrubs, including *Menziesia ferruginea*, *Rhododendron albiflorum*, *Ribes lacustre*, *Vaccinium membranaceum* and *Vaccinium ovalifolium*. In the upper portions, in which stand structure is much more open, shrubs are less common, and the understory is characteristically dominated by herbs, including *Erigeron peregrinus*, *Lupinus arcticus*, *Valeriana sitchensis* and *Veratrum viride*. For a more complete description of the vegetation, see Pojar and Meidinger (1991).

Distributional Patterns

Throughout most, and possibly all, of the ESSF, *Bryoria* displays at least seven obvious microscale and mesoscale patterns of distribution. These will be briefly discussed below.

1) Relations to Winter Snowpack

In boreal and oroboreal regions subject to deep winter snowpacks, hair lichens, including *Bryoria*, are typically absent from the lowermost branches of the lower canopy. In the study area, indeed, these lichens develop a distinct lower trimline at between 1.5 m and 2.5 m above the ground. That this trimline approximates the average maximum depth of the winter snowpack led Stevenson et al. (1994) to attribute it to mechanical damage exerted by the snowpack as it settles. While mechanical damage cannot be ruled out as a contributing factor, my own repeated observations suggest that *Bryoria* is excluded primarily through physiological sensitivity to prolonged exposure to snow.

This assertion is supported by the observation that fallen thalli lodged in the surface of the snow soon become matted, giving a moribund appearance. It is

also consistent with the observation that young trees in the ESSF generally support no *Bryoria* at all until they have become sufficiently tall to protrude through the surface of the winter snowpack — usually at twenty to fifty years of age, but in many cases much later still (Parish 1997). Given that diaspore availability is clearly not limiting to *Bryoria* dispersal in this zone (Goward, in preparation), and given that mechanical damage alone is unlikely to account for the complete absence of hair lichens over young trees, this pattern must be explained on other grounds. The most reasonable explanation would seem to involve an inherent inability to withstand prolonged burial within the winter snowpack. These observations must of course be confirmed by detailed studies of *Bryoria* ecophysiology.

2) *Relation to Foliated Branches and Defoliated Branches*

A striking and highly intriguing microdistributional pattern observed repeatedly among hair lichens is their general inability to successfully colonize the foliated portions of conifer branches. By contrast, these lichens regularly develop heavy loadings over defoliated portions of the same branches, often only a few centimetres away. This observation appears to be critical to an understanding of *Bryoria* ecology in the ESSF. In attempting to account for it, it is helpful to divide the canopy branches of a tree into two concentric zones: (1) an inner zone of brownish, defoliated branches; and (2) an outer zone of green, foliated branches. These zones will henceforward be referred to as the “defoliated zone” and the “foliated zone”, respectively. Both zones may of course be expressed along different portions of a single branch.

That *Bryoria* biomass is invariably much heavier in the defoliated zone than in the foliated zone may at first appear to be related to differences in age, the former zone having been available for colonization much longer than the latter zone. However, biomass discrepancies between these zones are generally much too pronounced and too sharp to be explained entirely on this basis: the transition between copious lichen loading on the one hand, and meagre lichen loading on the other hand often occurs over a horizontal distance of only 10 to 20 cm. What is more, it is difficult to reconcile these discrepancies with the prevalence of fragmentation as a mechanism of dispersal in *Bryoria*. Thallus fragments are continuously being redistributed through the canopy as a result of wind, snow clumping, and bird and mammal movements. Given the existence of such on-going “transplant experiments”, and given that conifer needles in the ESSF generally persist for a decade or more, it is inconceivable that at least some thallus fragments should not accumulate to conspicuous loadings among the needles of the foliated zone. This comment of course applies equally to the foliated zone of young sapling conifers, in which the ter-

minal branches have not yet protruded above the surface of the winter snowpack (see pattern 1, above).

During the early stages of this study, bark chemistry and/or bark texture was assumed to provide a plausible explanation for the relative absence of *Bryoria* over foliated branches. This explanation, however, appears to be inconsistent with the observation that hair lichens actually do routinely colonize foliated branches in certain (rather localized) habitats. Solitary trees growing in open bogs, for example, often support heavy mats of hair lichens over both the defoliated and foliated portions of branches. In some instances, indeed, lichen loadings may be sufficiently heavy to occasion the death of the branches. Trees growing in rather exposed situations along ridgecrests provide a similar instance, though foliated branches in this case are seldom killed. Taken together, these observations suggest either that bark chemistry and texture are not limiting to *Bryoria*, or, if they are, that their influence may be overridden by other factors. Stevenson (1985) reached a similar conclusion in her study of hair lichen ecology in coastal forests.

The evidence thus strongly suggests the existence of an active mechanism of *Bryoria* exclusion in the foliated zones of most trees. Here it may be observed that conifers, having a centrifugal architecture, tend to shed water outward, in the direction of the foliated zone (Barkman 1958). Given that the branches of the foliated zone thus remain wet much longer than the branches of the defoliated zone (see also the discussion under pattern 3, below), it is proposed that prolonged wetting may be at least partly responsible for the exclusion of *Bryoria* in the the former zone.

Such a wetting effect is especially pronounced during the winter months, when the foliated zone becomes blanketed with snow. In exposed or well-illuminated sites, the snow typically ablates rather rapidly, as a result either of wind or of direct warming by the sun. In sheltered or poorly illuminated sites, by contrast, the snow is likely to disappear more gradually, usually as a consequence of melting. Because the weight of the snow depresses the branches, it ensures that snowmelt is directed away from the trunk of the tree, in the direction of the branch tips (see Smith 1974). The extent to which a given foliated zone is subject to prolonged wetting doubtless depends on various complex details of architecture and exposure; but generally speaking, foliated branches positioned in sheltered situations may be expected to retain snowmelt much longer than other portions of a tree. The interception of rain, however, apparently operates according to very different principles (Satterlund and Haupt 1967).

By contrast, branch surfaces in the defoliated zone both receive less snow than their counterparts in the more exposed foliated zone, and provide comparatively meagre platforms for snow accumulation; they

therefore tend to shed snow comparatively rapidly. What is more, the dark colouration associated with *Bryoria* doubtless absorbs considerable heat, at least in illuminated sites, thus creating comparatively warm microclimatic conditions conducive to rapid snow melt. Viewed from this perspective, the existence of heavy hair lichen loadings over the defoliated, inner branches of a tree may be interpreted as an artifact of the ecologically "drier" conditions here.

3) Periodic Die-backs

During the spring and summer of 1997 — an anomalously wet period in southern British Columbia (Ralph Adams, personal communication) — *Bryoria* suffered a pronounced die-back in the study area. Most heavily affected were thalli that had become established over the foliated zone — presumably a result of thallus fragmentation. Thalli growing in the defoliated zone, by contrast, were largely unaffected by die-back. On branches over which both zones are expressed, it was possible to discern a continuum of thallus vigour consisting of at least three nodes: (1) an inner node of "healthy" thalli, in which the tips of the strands are divergent or at least discrete; (2) an intermediate node of apparently moribund thalli, in which the strand tips adhere to one another in a long, narrow, tapering "mustache"; and (3) an outer node of dead thalli, in which the strands are matted and clumped more or less throughout. Depending on aspect and degree of exposure, nodes 2 and 3 were restricted mostly to the foliated zone, though in sheltered sites node 2 was often found to extend inward to the outer portions of the defoliated zone. It would be interesting to discover whether, as seems likely, growth rates in *Bryoria* typically decrease outward along a branch in tandem with this continuum.

The situation was very different in the case of dead branches lacking a foliated zone. Here generally little evidence of *Bryoria* die-back was observed, even in the apical portions of the branches. This is an interesting observation. If, as seems likely, the apical portions of dead branches and the apical portions of living branches are subject to comparable levels of illumination, temperature, wind, and precipitation, then none of these factors seems likely to account for the observed differences in *Bryoria* loadings. Once again the most probable limiting factor, active solely in the foliated zone, would appear to be prolonged wetting.

Kershaw (1985) has already pointed to the existence in tree canopies of a "complex seasonal series of three-dimensional evaporative patterns" (his emphasis). Presumably as a result of these patterns, *Bryoria* undergoes seasonal readjustments to the prevailing climatic conditions: during periods of relative physiological drought, wind-dispersed fragments successfully colonize outward onto the foliated zone, whereas during the rest of the year, especially win-

ter, this genus tends to die back in the direction of the inner portions of the defoliated zone. Such trends must profoundly affect *Bryoria* growth rates in different portions of the canopy, with optimum rates doubtless shifting inward toward the trunk and outward toward the branch tips at different times during the course of a year.

4) Relation to Old Trees

A striking characteristic of old trees in the ESSF is their distinctly dark green colouration, as compared with the medium green colouration of adjacent younger trees. This colour difference extends to the forest itself, and may be discerned at considerable distances. Initially this discrepancy was assumed to be related to age-related differences in needle colour. Subsequent observation has revealed, however, that it in fact derives primarily from age-related differences in background *Bryoria* loadings. As already discussed in pattern 2, above, the development and extent of *Bryoria* loadings in a maturing tree closely parallel the development and extent of its inner defoliated zone. For convenience, the trajectory of both of these trends may be described in terms of the life history of a single branch.

In the earliest years of life, a branch is comprised entirely of a foliated zone; in the absence of a defoliated zone, it supports few if any colonies of *Bryoria*. After about ten or twelve years of age, however, the inner portion of the branch undergoes a degree of needle cast, thereby initiating a defoliated zone. From this point onward, the defoliated zone occupies an increasingly larger proportion of total branch length. Eventually the associated increasing dominance of hair lichens begins to cause a gradual darkening of the tree canopy. When eventually the branch dies, the foliated zone disappears. In its place the branch now consists entirely of a defoliated zone, over which a heavy loading of *Bryoria* soon becomes established. This trend to increasing dominance of hair lichens over the branch mirrors in microcosm the gradual increase in *Bryoria* over the tree as a whole. It is important to stress that the extent of *Bryoria* colonization on any given branch, and hence on any given tree, is dependent on the age of the branch, rather than on its size. Hence the observation, made on several separate occasions, that *Bryoria* loadings tend to be much heavier on old trees than on younger trees of similar size.

5) Occurrences in the Upper Crowns of Old Forests

As a rule, oldgrowth-dependent epiphytic lichens tend to be restricted to the lower canopy, in which within-stand microclimatic conditions are presumably favourable to their colonization; for a discussion, see McCune (1993) and Goward (1995). By contrast, few if any *Bryoria* species display a similar pattern in the oldgrowth forests of the ESSF. Here *Bryoria* loadings are routinely very heavy even when growing fully exposed to prevailing macroclimatic

conditions, as in the upper canopy of exposed trees. From this observation alone, it seems unlikely that the development of a heavy *Bryoria* biomass will be found to depend on special within-stand microclimatic conditions associated with oldgrowth forests. Instead, the positive correlation between increasing forest age and increasing hair lichen biomass appears to reflect the development of various structural features of ageing trees. In general, *Bryoria* appears to "read" the substrates associated with older trees as being less "humid" than those provided by younger trees. Thus, it is generally the age of individual trees, and not that of the forests in which they occur, which is of overriding importance to *Bryoria* loadings.

6) Relations to Young Trees in Exposed Sites

Heavy *Bryoria* loadings are usually associated with trees older than 100 to 150 years in age. Under some conditions, however, heavy loadings may develop in forest stands aged 70 years or even younger; see also Stevenson 1985. These younger stands are typically situated on ridgecrests or at the edges of clearings, though they may also occur in forests in which canopy structure is anomalously open. In either event the existence of heavy *Bryoria* loadings on young trees is invariably associated with sites exposed to high ventilation. Such observations strongly suggest that *Bryoria* growth rates are relatively rapid in the ESSF, and are unlikely by themselves to account for discrepancies in lichen biomass, at least in trees older than about 70 years; see also Renhorn and Esseen (1995).

7) Relation to Illumination

Repeated observation suggests that at least some species of *Bryoria* are able to persist at rather low levels of illumination. *Bryoria fuscescens*, for example, has been observed to occur in all but the most heavily shaded stands. In highly ventilated sites, such as isolated "tree islands" in the upper portions of the ESSF, *B. capillaris* and *B. pseudofuscens* may likewise achieve considerable loadings over branches subject to little direct sunlight. These observations suggest that low illumination per se is probably able to exclude these lichens only under exceptional conditions, and should thus not be considered limiting to *Bryoria* as a whole. On the other hand, shaded microsites subject to poor ventilation appear to favour *Alectoria sarmentosa* over *Bryoria* (Goward, in preparation).

A "Prolonged Wetting Hypothesis" for *Bryoria*

Stevenson (1985) has proposed that frequency of wetting and drying may play an important role in *Bryoria* ecology. By contrast, the observations recorded here suggest that duration of wetting is likely to be much more significant than frequency of wetting, at least in the ESSF. Indeed, the existing field evidence strongly supports the hypothesis that

the main features of *Bryoria* distribution and biomass may be accounted for by a sensitivity to prolonged wetting. More specifically, this hypothesis is supported by patterns 1, 2 and 3, and is consistent with patterns 4, 5, 6 and 7. What is more, patterns 2, 3, 5 and 7 seem to provide various lines of evidence in support of the reciprocal hypothesis, namely that other environmental factors — temperature, illumination, frequency of wetting and drying, substrate texture, substrate chemistry — are by themselves *not* limiting to *Bryoria* in the ESSF. The possibility does exist, of course, that such factors may in combination override duration of wetting as a dominant ecological force under at least some conditions. Even so, it is difficult to avoid the conclusion that prolonged wetting is of considerable importance in the ecology of these lichens in the ESSF as a whole.

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The Diet of Nesting Ospreys, *Pandion haliaetus*, in Labrador

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We examined the diet of nesting Ospreys (*Pandion haliaetus*) along the Naskaupi River in Labrador during 1995 and 1996. Observations of Ospreys feeding on identifiable prey species provided an indication of available food supply and summer diet for this population. Mammals and birds may constitute important food sources. Prey consumption dropped from 7.5% and 5.0% for mammals and birds, respectively, in 1995 to 0% in 1996, coinciding with a regional crash in the small mammal population. Inclement weather during 1996 also may have been a factor in lowering productivity.

Key Words: Osprey, *Pandion haliaetus*, diet, feeding, fish, mammals, Labrador.

Ospreys (*Pandion haliaetus*) consume a variety of prey species, depending upon regional availability (Swenson 1978; Van Daele and Van Daele 1982; Poole 1985). Although Ospreys are considered mainly piscivorous, numerous accounts of non-fish prey have been recorded for this species. Ospreys have been observed carrying a variety of non-fish prey including aquatic and terrestrial birds, small mammals, reptiles, amphibians and invertebrates (see Wiley and Lohrer 1973 for literature review). A variety of reasons have been suggested for non-fish prey items in the diet of Ospreys including scarcity of fish due to a kill, murky water or inclement weather, lack of fishing skill due to youth, easily captured crippled birds and abundance of an alternative food source (Wiley and Lohrer 1973). Non-fish prey items are also brought to the nest to be used as building or lining material (Postupalsky personal communication, cited in Vana-Miller 1987).

We believe that the presence of mammals in Ospreys' diet in 1995 reflected higher microtine populations. In 1996, following a crash in the mammal population (Jacques Whitford Environment Ltd., unpublished data) mice and voles were no longer available. Changes in prey availability coupled with inclement weather conditions may have altered Osprey diet and lowered productivity.

Study Area and Methods

The study area lies within the High Boreal Forest-Lake Melville ecoregion (Lopoukhine et al. 1977; Meades 1990*), consisting of taiga, subalpine tundra, and transitional vegetation types of central

Labrador. Stands of Black Spruce (*Picea mariana*) and Balsam Fir (*Abies balsamea*) occur on shallow upland soils whereas open spruce lichen forest can be found on upland till and outwash soils. White Birch (*Betula papyifera*) and Trembling Aspen (*Populus tremuloides*) occur on well-drained alluvium soil. Alder (*Alnus rugosa*), White Birch, willows (*Salix* sp.), and Balsam Poplar (*Populus balsamifera*) dominate riverine habitats.

This region has long, severe winters with heavy snow accumulation and short summers. Snow normally begins in October and may persist into June. Mean daily temperature ranges from -14 to -18°C in February to 13°C in July. Average annual precipitation is 1100 mm with an average snowfall accumulation of 4 m. Median ice-free date is 10 June (Wetmore and Gillespie 1976).

Observations were made along the Naskaupi River in Labrador during the summers of 1995 and 1996 as part of a larger study on the effect of military aircraft on Osprey behavior (Trimper et al. 1998) in the Low-Level Training Area (LLTA). Ospreys return to this area from southern wintering grounds in early May and initiate egg-laying in late May to early June. Osprey pairs nest solitarily, in relatively low densities, throughout the LLTA and do not occur in colonies (Wetmore and Gillespie 1976 [Department of National Defense (DND) unpublished data]). Our study nests (N = 5) were located within 50 m of the Naskaupi River or its tributaries in large co-dominant spruce trees. The five nests had a mean separation distance of 7.5 km and were all within a 30-km section of the river (see Figure 1).

Observation blinds were located 100-200 m from each Osprey nest along the Naskaupi River. Osprey behavior was monitored using 10-40× tripod-mounted spotting scopes. Observations generally

*See Documents Cited section.

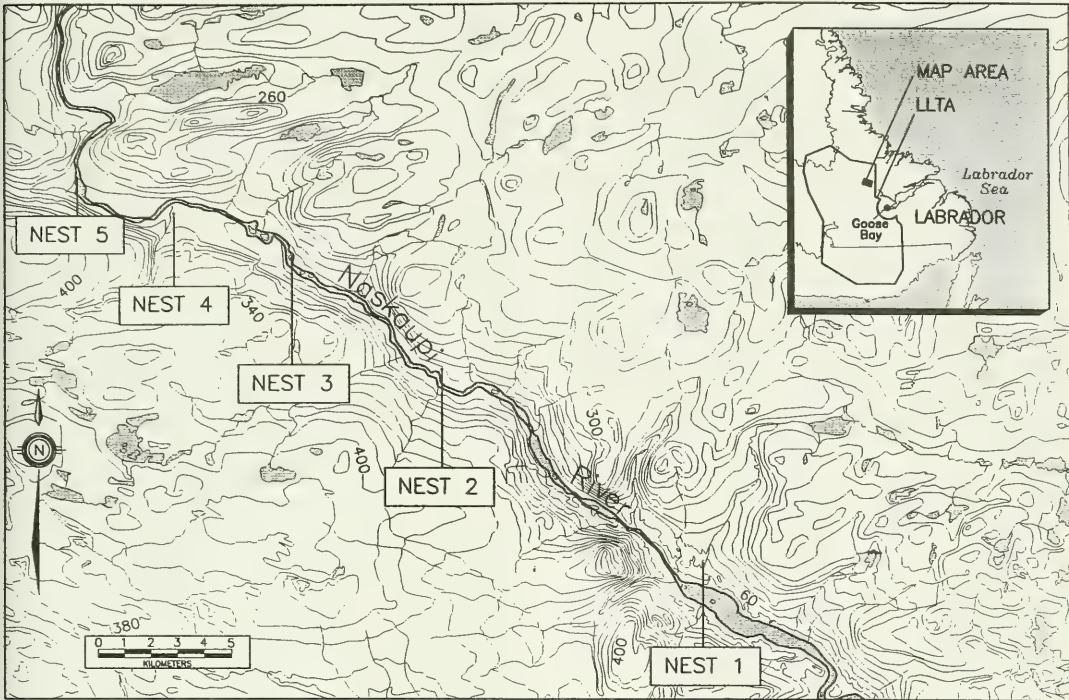


FIGURE 1. Locations of Osprey study nests along the Naskaupi River in Labrador. Elevations are shown in meters.

occurred between 08:30 and 17:00 hrs over two days during each of five periods of nest activity (early and late incubation, hatch, early nestling and pre-fledging). We collated 240 and 201 hrs of observations in 1995 and 1996 respectively, from which we determined dietary use.

Prey identification was made to the highest taxon possible, and size was estimated by comparing prey length to that of the bird (Poole 1982). In 22 (14%) cases, Ospreys were recorded feeding on prey items that were not identifiable. These incidents were excluded in determining dietary use. We used Chi-square tests to determine significant differences in proportion of species in the diet.

Results and Discussion

Fifteen species of fish have been recorded in the Naskaupi River (Anderson 1985). Ospreys were observed feeding on a variety of fish species including Speckled Trout (*Salvelinus fontinalis*), Northern Pike (*Esox lucius*) and suckers, either Longnose Sucker (*Catostomus catostomus*) or White Sucker (*Catostomus commersoni*). The four observations of microtines were possibly Woodland Jumping Mice (*Napaeozapus insignis*), Meadow Jumping Mice (*Zapus hudsonius*), or Deer Mice (*Peromyscus maniculatus*). On two occasions, mammals were identified as voles (*Microtus pennsylvanicus* or *Clethrionomys gapperi*). Bird species

taken as prey were identified as small, sparrow-sized passerines.

Among the 80 occurrences of Ospreys feeding on identified food items during the summer of 1995 along the Naskaupi River, 70 (87.5%) involved fish, 6 (7.5%) were small mammals and 4 (5.0%) were birds (Table 1). In 1996, no avian or mammalian prey species were recorded and fish comprised 100% of the observed diet. This coincided with a regional crash in the small mammal population during 1996 (Jacques Whitford Environment Ltd. unpublished data; Wildlife Division unpublished data). In most cases, as has been observed in other studies (Poole 1989; Steeger and Ydenberg 1993), prey size (specifically fish species) was difficult to record accurately. However, we recorded an average fish size of 25 cm (range 13-40 cm) over both years. This is similar to average fish lengths reported in the literature (Van Daele and Van Daele 1982).

Our observations revealed that male Ospreys provided 88% and 94.5% of food deliveries to the nest in 1995 and 1996, respectively. This is similar to male food deliveries in other studies (Van Daele and Van Daele 1982). All five nests had at least one non-fish prey item delivered in 1995 and on two occasions, the female at nest two was observed delivering small mammals to the nest. Clutch sizes remained constant in both years with all five nests producing three eggs each. Hatch rate was 100% in 1995 but

TABLE 1. Occurrence of identified prey items in the diet of nesting Ospreys, Naskaupi River, Labrador, 1995-1996

Breeding Stage	Fish ^a		Trout		Pike		Sucker		Mammal		Bird		Total	
	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996	1995	1996
Early Incubation	8	4	5	3	0	0	0	0	2	0	1	0	16	7
Late Incubation	4	5	2	5	0	0	0	0	0	0	0	0	6	10
Hatch	14	9	4	11	1	0	1	0	2	0	0	0	22	20
Early Nestling	13	11	5	6	0	0	0	0	0	0	0	0	18	17
Pre-fledging	11	0	2	1	0	0	0	0	2	0	3	0	18	1
Total	50	29	18	26	1	0	1	0	6	0	4	0	80	55
%	62.5	52.7	22.5	47.3	1.3	0.0	1.3	0.0	7.5	0.0	5.0	0.0	100	100

^aUnidentified fish species

only two of five nests produced hatchlings in 1996. Productivity dropped from 2.4 young fledged per nest in 1995 to 0.6 in 1996, apparently due to increased hatchling mortality rather than brood reduction, which is commonly associated with low food abundance (Hagan 1986; Bowman et al.1989). As indicated by identifiable prey items delivered to the nest, small mammals constituted significantly less in 1996 than in 1995 ($\chi^2 = 7.7$, $df = 3$, $P < 0.05$). Also, in 1996, no birds were observed as prey items. Ospreys delivered fewer prey items in 1996 (4.6 prey/day) than in 1995 (5.5 prey/day). This difference was also observed in the number of fish delivered to the nest with rates decreasing from 4.2 fish/day in 1995 to 3.9 fish/day in 1996. A 40% increase in average rainfall and corresponding 2°C decrease in mean monthly temperature in July 1996 (Goose Bay Monthly Meteorological Summary, Environment Canada), as compared to 1995, may have made fish less available as prey, thus lowering productivity.

The lowered productivity and varied diet observed in this study may have been due to a combination of variables. Heavy rainfall and lower temperatures during brood rearing in July may have lowered nestling survival. Increased water depth and turbidity may have lowered the catch of fish due to silting and higher water levels. A crash in the microtine population appears to have eliminated an alternate food source that may be an important component of the diet of this northern population.

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New Records from the Northern Range of the Plains Spadefoot Toad, *Spea bombifrons*, in Alberta

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Lauzon, Richard D., and Peter Balagus. 1998. New records from the northern range of the Plains Spadefoot Toad, *Scaphiopus bombifrons*, in Alberta. *Canadian Field Naturalist* 112(2): 506–509.

Plains Spadefoot Toads were observed or heard calling in numerous ponds between Veteran and Youngstown, Alberta, during mid-June 1996. Juvenile Plains Spadefoot Toads were observed north of Youngstown in September 1996. The range of the Plains Spadefoot Toad in Alberta is predominantly south of the Red Deer River. There are three unpublished locations north of the Red Deer River at Dillberry Lake Provincial Park, Reflex Lakes, and Sounding Lake. Our observations verify the existence of the Plains Spadefoot Toad north of the Red Deer River in Alberta.

Key Words: Plains Spadefoot Toad, *Spea bombifrons*, range extension, Alberta.

The Plains Spadefoot Toad, *Spea bombifrons* (often placed in *Scaphiopus* but see Tanner 1989; Wiens and Titus 1991, and references therein*) is a blue-listed species in Alberta (Alberta Environmental Protection 1996). Blue-listed species include those species which may be at risk or which may have too limited information to clearly define their status. Although Saskatchewan presently has no legal status for wildlife species, legislation is currently in process and an endangered species list will be prepared (Earl Wiltse, personal communication). Nationally, the Plains Spadefoot Toad is not included in the COSEWIC list of endangered species. A status report is currently being prepared and the status of this species will be examined in the future (Andrew Didiuk, personal communication).

Within Alberta, the present known range of the Plains Spadefoot Toad, *Spea bombifrons*, encompasses southern Alberta from the Montana border north to the Red Deer River and from the Saskatchewan border west to Pincher Creek (Russell and Bauer 1993) (Figure 1). This information obtained from Russell and Bauer (1993) is based on collections at the National Museum of Canada, American Museum of Natural History, University of Alberta, personal communications to Anthony Russell and localities published by Moore (1952) and Lewin (1963). Additional unpublished records from north of the Red Deer River include two in the vicinity of Dillberry Lake Provincial Park and one near Sounding Lake. Several Plains Spadefoot Toad tadpoles and a metamorph were collected in 1971

just north of Dillberry Lake (52°36'N, 110°01'W) and placed in the University of Alberta zoology collection (Catalogue numbers UAMZ 1965 and UAMZ 2001) (Figure 1). Plains Spadefoot Toads were observed near Reflex Lakes in 1989 by Cliff Wallis (52°40'N, 110°02'W) and north of Sounding Lake in May 1983 by Cliff Wallis and Cleve Wershler (52°15'N, 110°34'W) (Cleve Wershler, personal communication) (Figure 1). Recently, Plains Spadefoot Toads have also been observed south of Hanna, Alberta, near Coleman Lake (51°25'N, 111°53'W) and near Blood Indian Reservoir south of Youngstown (51°16'N, 111°11'W) by Ed Hoffman, provincial wildlife biologist (personal communication) (Figure 1).

In Saskatchewan, the range of the Plains Spadefoot Toad extends north to Alsask (51°21'N, 109°59'W) (Moore 1952) (Figure 1), Conquest (51°34'N, 107°08'W) (Andrew Didiuk, personal communication), and Outlook (51°30'N, 107°03'W) (Morlan and Matthews 1992). Alsask is on the Alberta-Saskatchewan border, north of the Red Deer River.

Fossil remains of Plains Spadefoot Toads and Great Plains Toads, *Bufo cognatus*, have been found near Killam, Alberta (52°48'N, 111°51'W) (Bayrock 1964) (Figure 1). These remains were found in a post-glacial sand deposit within the Parkland Ecoregion. There is no Carbon-14 date for the remains, however it is estimated that they lived 4000 to 7000 years ago during warmer post-glacial times (Bayrock 1964). Fossil remains have also been found along the South Saskatchewan River south of Saskatoon, Saskatchewan. It could not be determined, however whether these remains are from that area or if they had washed downstream from a location further south (Richard Morlan (Canadian Museum of Civilization) personal communication to Francis Cook).

*Editors note: However, a recent account argues for continued use of *Scaphiopus* on the genus for all North American spadefoots. Hall, J. A. 1998. *Scaphiopus intermontanus*. Catalogue of American Amphibians and Reptiles. Society for the Study of Amphibians and Reptiles 650.1–650.17.

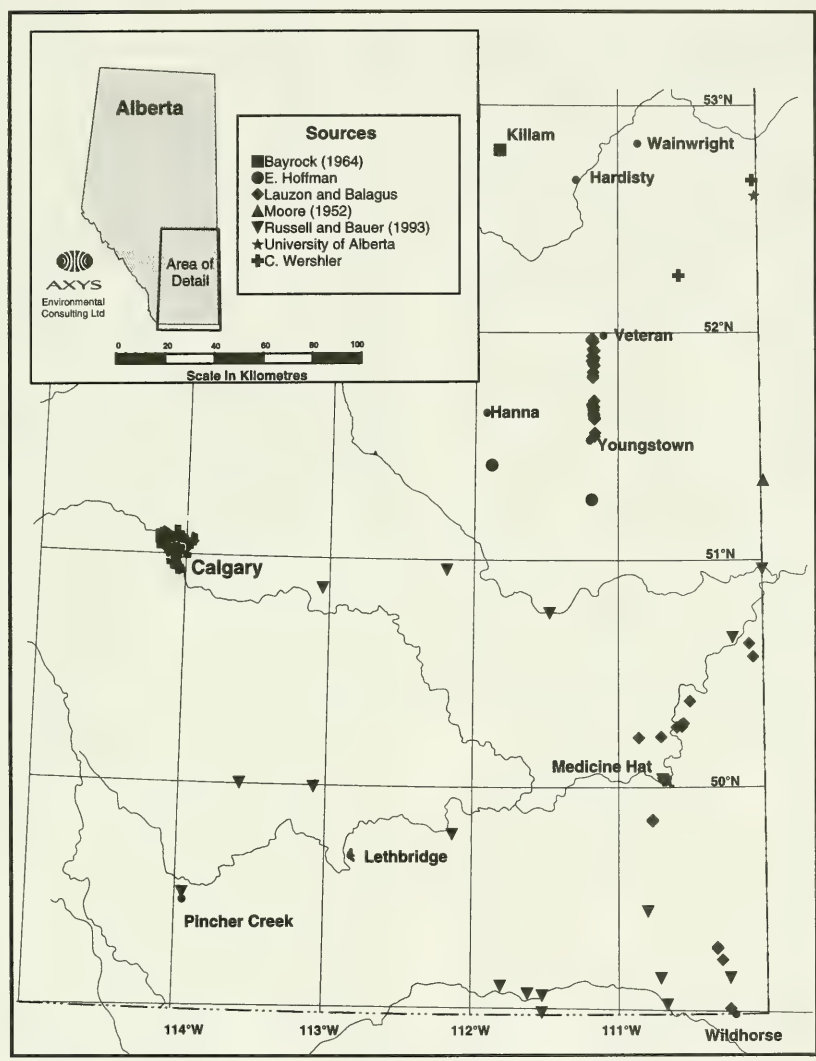


FIGURE 1. Distribution of the Plains Spadefoot Toad in Alberta including prehistoric, published and recent observations.

Current published information indicates that the Plains Spadefoot Toad is found only within the Grassland Ecoregions of Alberta as defined by Strong and Leggat (1992). The observations near Dillberry Lake Provincial Park, Reflex Lakes, and Sounding Lake indicate that the spadefoot also inhabits areas within the Aspen Parkland region (Strong and Leggat 1992). Although all current records in Saskatchewan are within Grassland Ecoregions (Padbury and Acton 1994), in Manitoba, the Plains Spadefoot Toad has also been found within the Aspen Parkland near Dauphin and at Oak Lake (Cook and Hatch 1964).

As part of a comprehensive wildlife survey for a pipeline development in eastern Alberta, Axys

Environmental Consulting Ltd. was retained to conduct a nocturnal calling survey for frogs and toads. The purpose of the survey was to identify breeding ponds within a 500 m corridor centered on the proposed pipeline for a number of provincially sensitive species, which included the Plains Spadefoot Toad. The survey was conducted from 21 May to 27 June 1996. The study area included a 435 km linear corridor from Hardisty to Wildhorse.

During the course of the survey, concentrations of Plains Spadefoot Toads were observed or heard calling in areas that would verify the range north of the Red Deer River in Alberta (Figure 1). A total of 40 ponds were identified with calling individuals (Table 1). Thirty-four of the ponds are located north of the

TABLE 1. Locations of wetlands where Plains Spadefoot Toads were heard or observed, and numbers of individuals heard or observed, during late-May and June amphibian surveys in eastern Alberta.

Date	Number of	Longitude	Latitude
Heard/ Observed	Individuals		
6 June	5-10	51° 58' 19"	111° 10' 39"
6 June	<5	51° 58' 15"	111° 11' 06"
6 June	<5	51° 57' 46"	111° 11' 11"
6 June	5-10	51° 57' 36"	111° 10' 23"
6 June	>10	51° 55' 37"	111° 10' 33"
6 June	5-10	51° 55' 14"	111° 09' 51"
6 June	5-10	51° 55' 11"	111° 10' 12"
7 June	<5	51° 53' 47"	111° 10' 54"
7 June	5-10	51° 53' 21"	111° 09' 56"
7 June	<5	51° 57' 36"	111° 10' 09"
7 June	>10	51° 55' 37"	111° 10' 28"
7 June	<5	51° 55' 14"	111° 10' 54"
7 June	<5	51° 55' 11"	111° 10' 59"
7 June	5-10	51° 51' 44"	111° 10' 27"
7 June	>10	51° 51' 39"	111° 10' 15"
7 June	>10	51° 51' 19"	111° 09' 54"
7 June	5-10	51° 49' 32"	111° 10' 30"
7 June	<5	51° 49' 32"	111° 10' 25"
7 June	5-10	51° 48' 34"	111° 10' 30"
7 June	5-10	51° 48' 08"	111° 10' 30"
7 June	<5	51° 42' 03"	111° 09' 57"
8 June	5-10	51° 40' 58"	111° 10' 54"
8 June	<5	51° 40' 29"	111° 10' 33"
8 June	<5	51° 40' 22"	111° 10' 02"
8 June	5-10	51° 39' 37"	111° 10' 18"
8 June	5-10	51° 38' 45"	111° 10' 17"
8 June	5-10	51° 38' 26"	111° 09' 56"
8 June	5-10	51° 38' 13"	111° 10' 17"
8 June	>10	51° 37' 34"	111° 09' 55"
8 June	<5	51° 37' 24"	111° 09' 41"
9 June	5-10	51° 37' 18"	111° 09' 46"
8 June	5-10	51° 37' 11"	111° 09' 51"
10 June	5-10	51° 33' 34"	111° 09' 35"
10 June	5-10	51° 32' 39"	111° 09' 50"
29 May	1	49° 51' 21"	110° 46' 04"
29 May	3	49° 51' 01"	110° 46' 09"
2 May	1	49° 17' 33"	110° 20' 04"
2 May	1	49° 17' 11"	110° 20' 04"
3 June	3	49° 14' 12"	110° 18' 05"
13 June	1	49° 01' 20"	110° 14' 58"

Red Deer River. All Plains Spadefoot Toad breeding ponds were found in, or adjacent to, areas with sandy soils (Laura Morrison, personal communication). All Plains Spadefoot Toad breeding ponds were ephemeral and most were dry by August. Habitats adjacent to breeding wetlands included native grassland, native grassland/shrub mix, improved pasture, and hayland. Improved pasture and hayland vegetation communities were usually comprised of non-native plant species. Canadian

Toads, *Bufo hemiophrys*, were also heard or observed in many of the wetlands where spadefoots occurred, north of Youngstown.

While we were monitoring construction activities during September 1996, we found numerous juvenile Plains Spadefoot Toads and juvenile Canadian Toads along a sandy road just north of Youngstown. This area is adjacent to several of the breeding wetlands identified during late spring surveys. The juvenile Plains Spadefoot Toads were observed during overcast conditions after rain, whereas juvenile Canadian Toads were also found during sunny weather. Juvenile Plains Spadefoot Toads were observed as late as 17 September.

A desiccated adult Plains Spadefoot Toad was found by the senior author on 5 September 1996 north of Youngstown, in the vicinity of other Plains Spadefoot Toad locations (51°41'36"N, 111°10'12"W). The toad was found in a sandy blowout in the vicinity of a dry ephemeral wetland and was later placed in the University of Calgary zoology collection (Catalogue number UCMZ (A) 1996.006). Photographs were taken of an adult Plains Spadefoot Toad captured at one of the northern locations on 6 June 1996, and of a juvenile Plains Spadefoot Toad caught on the sandy road north of Youngstown, 5 September 1996.

Axys Environmental Consulting Ltd. was retained by Alberta Energy Corporation to conduct amphibian surveys during late-May 1997 for a pipeline project in the Medicine Hat region. During the course of this survey, Plains Spadefoot Toads and Great Plains Toads were heard or observed in 11 wetlands (Figure 1). Although these locations are within the known range of the spadefoot, most of the wetlands are new locations for this species within Alberta. All spadefoot toads were located in native grassland or grassland/shrub habitats with sandy soils. It is interesting to note that Plains Spadefoot Toads and Great Plains Toads were not heard or observed in the study area until after heavy rains fell from 23 to 25 May 1997. The number of spadefoot toads heard calling from these wetlands ranged from one to more than 20.

Our observations and the records near Dillberry Lake Provincial Park, Reflex Lakes and Sounding Lake, show that the Plains Spadefoot Toad is more widespread and extends further north than previously published information indicates. In light of this, it is possible that the Plains Spadefoot Toad may still occur in the Killam area as well as other areas of sandy soils within the Parkland and Grassland Ecoregions. Such sandy habitats can be found at Wainwright and southeast of Hardisty. It is also reasonable to speculate that the Plains Spadefoot Toad is likely to be found in sandhill areas in the Parkland Ecoregion of Saskatchewan, such as those at Manitou Lake, south of Lloydminster and west of Saskatoon.

Acknowledgments

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Notes

Post-dispersal Seed Predation in the Temperate Rainforest of Southeast Alaska

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Bermejo, Teresa, Anna Traveset, and Mary F. Willson. 1998. Post-dispersal seed predation in the temperate rainforest of southeast Alaska. *Canadian Field-Naturalist* 112(3): 510–512.

Post-dispersal predation on seeds of vertebrate-dispersed plants (*Rubus spectabilis*, *Oplopanax horridus*, and *Streptopus amplexifolius*) of the temperate rainforest of southeast Alaska was experimentally examined comparing “clean” seeds with seeds embedded in feces of bears, important dispersers in the area, and comparing also different microhabitats where seeds may be dropped or defecated. It was found that seed removal was significantly higher for clean seeds than for seeds within bear feces, and that levels of seed predation were similar for seeds under plants of the same species and for seeds under plants of other species. These results indicate that seed predators (presumably mostly rodents) use neither fecal material nor the presence of a conspecific plant as a clue to the location of seeds.

Key Words: Southeast Alaska, seed predation, seed dispersal, rainforest, bears, rodents.

The seeds of many species of plants with fleshy fruits are dispersed by vertebrates, commonly by passing through the digestive tract and being deposited on the ground in feces. Presence of fecal material may provide fertilizer for the seedlings, but large deposits of seeds may also attract seed predators (e.g., Janzen 1982, 1986; Willson 1989). Furthermore, proximity to a conspecific plant or density of dispersed seeds often increases the risk of predation (e.g., Janzen 1971; Willson and Whelan 1990; Schupp 1988a,b; Traveset 1990; Hulme 1994). We experimentally examined the effect of conspecific plants and bear feces on the risk of predation to seeds of three species of fleshy-fruited plants (Salmonberry, *Rubus spectabilis* [Rosaceae]; Devil's Club, *Oplopanax horridus* [Araliaceae]; and Clasping Twisted-stalk, *Streptopus amplexifolius* [Liliaceae]) which are relatively common in the temperate rainforests of southeast Alaska (Pojar and MacKinnon 1994). The main seed dispersers of these plants in this area are both bears and birds (Traveset and Willson 1997).

Methods

Field work took place within the area of Juneau, Alaska, during July and August of 1994 in four localities, separated by at least 6 km apart. Three of the sites [2-Mile (2M), Herbert River (HR), and Thane Road (TR)] are located within large expanses of mature temperate rainforest of Western

Hemlock (*Tsuga heterophylla*) and Sitka Spruce (*Picea sitchensis*). The other site, Sheep Creek valley(SC), supports mostly deciduous vegetation, including Salmonberry (*Rubus*), Elderberry (*Sambucus*), High-bush Cranberry (*Viburnum*), Sitka Alder (*Alnus*), and Black Cottonwood (*Populus*).

Seeds of the three study species were gathered from fruits collected from several different individuals. Groups of 50 seeds of each species were used in the two treatments: (1) “cleaned” seeds, which were placed in 5 cm aluminum dishes, perforated to drain rain water away and (2) seeds embedded in what we called “pseudofeces”, hand-made balls made with dung of Brown Bears (*Ursus arctos*). This dung was collected on Chichagof Island (Alexander Archipelago), was fresh when employed and contained vegetal material but no seeds. Both aluminum dishes and pseudofeces were separately placed on thin 15 × 15 cm wooden trays to avoid losing them in the forest.

In each locality, the experimental presentations were laid out on a transect parallel to an existing trail. Five plots, each separated by 75 m, were chosen along the transect. In each plot, we located three plants of each study species, separated by a distance of at least 3 m. Under each plant we placed a tray with seeds in an aluminum dish and a tray with seed-bearing feces. One plant of each species received trays with the same species of seed, and

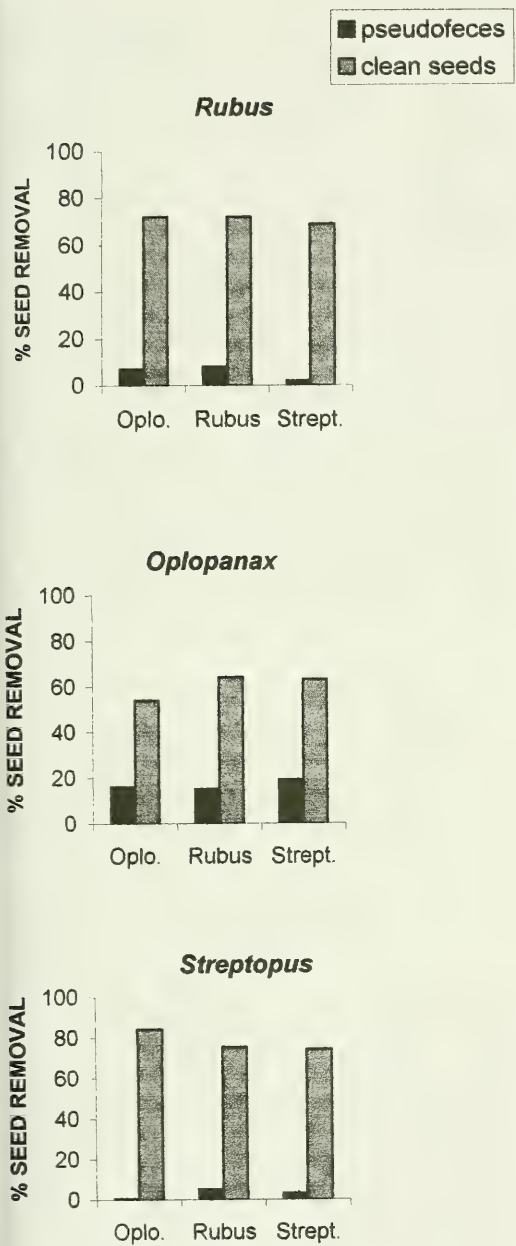


FIGURE 1. Mean percentage of seed removal, for each of the three species, observed in each treatment (clean seeds vs. seeds in pseudofeces) and in each microsite (under *Oplopanax*, *Rubus*, or *Streptopus* plants) during the fruiting season of 1994.

the other two received trays with the other species of seed. After 4-5 days, seed removal was checked in each plot (recording also the number of broken seeds present), and the experiment was repeated at the next set of consecutive plots along the transect,

for a total of three trials per site. A total of 15 plots (replicates) were chosen in three localities (2M, TR and SC) whereas only 10 plots (two replicates) could be used in the other locality (HR). Experiments lasted about three weeks, from 18 July through 9 August.

Because in Sheep Creek we could not locate enough *Streptopus* individuals in each plot, we decided to use the closest area (TR) where this species is abundant to place the trays in order to have an orthogonal experimental design. Considering all areas together, a total of 120 trays, half with clean seeds and half with pseudofeces, were placed for each species.

Data were analysed by a fully crossed ANOVA with three fixed effects: species, microsite (plant species underneath which seeds were placed) and treatment (clean seeds and pseudofeces). Data from all sites were pooled after knowing that no differences existed among them. The proportion of seeds removed from each tray was the dependent variable, which was normalized with the angular transformation before doing the analyses. SYSTAT for Windows (1992) was the statistical package used for all analyses.

Results

Seeds were removed significantly more often from the dishes than from the pseudofeces (Table 1), and this was evident in all three species of seed (Figure 1). The effect of clean seeds was stronger for *Streptopus* than for the two other species (Figure 1; significant interaction term for species \times treatment [Table 1]). Neither species nor microsite had a significant effect on overall seed removal (Table 1).

Seed coat fragments of the study species were often found on the trays. Such fragments were those typically left by rodents after these eat the endosperm. Red Squirrels (*Tamiasciurus hudsonicus*), several species of voles (*Microtus spp.*) and Deer Mouse (*Peromyscus maniculatus*) are com-

TABLE 1. ANOVA results of percentage of seed removal for the effect of species (*Rubus*, *Oplopanax*, and *Streptopus*), treatment ("cleaned" seeds, seeds in pseudofeces) and microsite (underneath plants of the three study species) after 4-5 days of placement. Data were arcsine-square root transformed. *** $P=0.0001$

Source of Variation	df	MS	F
Species	2	0.24	1.41
Treatment	1	154.27	882.87 ***
Microsite	2	0.02	0.14
Species \times Treatment	2	3.93	22.52 ***
Species \times Microsite	4	0.11	0.60
Treatment \times Microsite	2	0.03	0.16
Species \times Treatment \times Microsite	4	0.15	0.87

mon in the area, and we strongly believe these animals were mainly responsible for the seed predation observed. Seed-eating birds such as Dark-eyed Juncos (*Junco hyemalis*) have sometimes been observed picking seeds from bear dung, and it might well be that they have contributed to some of the seed removal. No ants exist in the area, so they certainly cannot be responsible for any seed removal.

Discussion

Rodents commonly use olfaction in food detection (Hulme 1993), and it has been hypothesized that feces might act as an olfactory cue to the presence of numerous seeds. However, we found that clean seeds were removed significantly more often than seeds inside bear feces. One possible explanation for these results is that rodents search in bear feces when they do not find clean seeds in the area. Actually, in all cases where seeds were removed from pseudofeces, the majority of clean seeds had also been removed.

High concentrations of clean seeds on the forest ground are infrequent. Fruits dropped by the plant are rapidly detected by animals and eaten, whereas "almost clean" seeds that have been defecated or regurgitated by birds are regularly found scattered in an area. Future research is warranted in comparing the probability of survival of seeds from bear dung to that of seeds from the rapidly decomposing feces of fruit-eating birds, which typically contain few seeds.

Bears commonly deposit hundreds and thousands of seeds of each of the study species in a single defecation and, thus, are potentially important dispersers for these plants. However, the rich seed deposits are subject to potentially high risks of predation. On Chichagof Island, we have observed bear feces scattered by the seed-foraging of rodents, sometimes to a distance of over a meter from the original deposit, and with most seeds removed. These risks of predation most likely vary greatly with the dramatic fluctuations of rodent populations, and many dung deposits in the field are actually not depredated (MFW, personal observation).

The lack of association between microsite and seed predation suggests either that rodents are not more likely to consume seeds that are near a conspecific plant or that rodents were so ubiquitous that any kind of selection was masked.

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Does the Whitlow-grass *Draba sibirica* (Pall.) Thell. Occur in North America?

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Berkutenko, Alexandra N. 1998. Does the whitlow-grass *Draba sibirica* (Pall.) Thell. occur in North America? Canadian Field Naturalist 112(3): 513–515.

The examination of the types of the whitlow-grasses *Draba longipes* Raup and *D. kananaskis* Mulligan leads to the conclusion that both of these names are synonyms of *D. juvenilis* Komarov.

Key Words: Whitlow-grass, *Draba sibirica*, *D. longipes*, *D. ogilviensis*, *D. kananaskis*, *D. juvenilis*, Alaska, Yukon, British Columbia, Kamchatka, Magadan region, amphiberian.

Eric Hultén (1973) made an attempt to correlate the Russian and American concept of those species which occur, or are presumed to occur, on both sides of Bering Strait. He emphasized that there is a remarkable parallelism in the flora of the northern parts of the two continents. As a result of his investigation of herbarium specimens in the Komarov Botanical Institute at St.-Petersburg, he placed in synonymy some names of superfluously described species when he discovered that some species show the same variation on both sides of Bering Strait. Here, I compare the Whitlow-grass (Whitlow wort), *Draba*, species that were described and considered as either only Asiatic or only North American but which, in fact, are the same form on both sides of the Bering Strait and actually represent only one species.

An examination of the types of *Draba juvenilis* Kom. (Holotype: "Kamchatka, upper Kashkan river, basin of Kashkan near Putschino settlement, 24 July 1909 V. L. Komarov LE!") and *D. longipes* Raup (Isotype: British Columbia, west and northwest slopes of Mt. Selwyn, about 56° 01'N, 123° 39'W, July 26, 1932 Coll. H. M. Raup, 4122 LE!) showed them to be the same species (Berkutenko 1978). Before this, *D. juvenilis* was considered to be an Asiatic species distributed, in addition to Kamchatka, from Olenek and Lena basin to the Bering sea. It is very common in Chukotka and Tolmachev (1975) presumed that it occurred in the north-west of North America but the species was not recognized by researchers on Alaska-Canadian flora. Findings of *D. juvenilis* in Taimyr (Kozhevnikov 1996) and to the south of the Magadan region (Berkutenko 1983) enlarged the area of this species in Asia. I sent G. Mulligan, specialist in North American *Draba*, duplicates of *D. juvenilis* from Severo-Evensk district of Magadan region and Chukotka. He determined them as *D. longipes*. According to Mulligan (1971) the range of *D. longipes* is Alaska, Yukon, north of British Columbia and western District of Mackenzie. A. V. Porsild (1974) mentioned *D. longipes* as one of the very common species of the Yukon Territory, where

it grows on wet alpine meadows. Thus, due to the isolated investigations of the flora on both sides of Bering Strait, one species was described twice. Raup described *D. longipes* 20 years later than Komarov, therefore prior name for this amphiberian species is *D. juvenilis* Kom. In both parts of the area, in Asia and in North America, this species has a similar ecology and the same range of morphological variation, especially in flower colour: petals can be whitish, yellowish and yellow.

In 1993, I had the opportunity to examine samples of *D. ogilviensis* Hultén in the Museum of the University of Alaska in Fairbanks. Hultén (1966) had described *D. ogilviensis* from the Ogilvie Mountains in southwestern Yukon Territory. Subsequently there were differing opinions about *D. ogilviensis* among botanists. A. E. Porsild (1974) considered *D. ogilviensis* a synonym of *D. sibirica* (Pall.) Thell. The first report of *D. sibirica* from North America (Porsild 1964) was based on flowering fragments found among other plants regularly "harvested" by the collared lemming in the Ogilvie Mountains. These were brought to Porsild for identification in 1963 by zoologists P. M. Youngman and G. Tessier. Porsild (1974) had an abundant series of the Yukon plant as well as the large series reported from the central Mackenzie Mountains in western District of Mackenzie and (Porsild 1974, page 37) compared these "with other specimens of *D. sibirica* representative of its peculiarly discontinuous range from central East Greenland, the Ural Mountains, Waigatsch Island, and the adjacent mainland of arctic Russia, including the west Caucasus Mountains, the lower Lena River of eastern Siberia, the Chukotsk peninsula, and East Cape". On this basis Porsild (1974, page 37) concluded: "*D. ogilviensis* Hult., proposed for the Yukon plant, is therefore superfluous and must be rejected". *D. sibirica* does not occur in the Chukotsk peninsula, East Cape and lower Lena River. The most eastern locations of *D. sibirica* are in the Magadan region on the north shore of Okhotsk sea: Gishiga and Garmanda river (Tolmachev 1975). Throughout the whole area from

the Don basin in Europe to sea of Okhotsk in Asia *D. sibirica* is characterized by malpighian pubescence. There is no indication of malpighian pubescence in the description of *D. ogilviensis* Hult. Bocher (1974) was not sure about the taxonomic rank of plants from Ogilvie mountains and presumed that perhaps they deserved subspecies rank within *D. sibirica*. Mulligan (1976) received seeds from the Ogilvie Mountains for growing in a greenhouse. His opinion was that *D. ogilviensis* resembled *D. sibirica* but did not have malpighian hairs which are typical of *D. sibirica*. Mulligan examined all of the specimens identified by Porsild and none of them have malpighian hairs. In fact none of the North American material of *D. olivensis* has malpighian hair according to Mulligan. However, Mulligan (1976) has shown that *D. ogilviensis* has the same chromosome number as *D. sibirica*, $2n=16$. He believes that they are closely related. *Draba longipes* (here called *D. juvenilis*) and *D. kananaskis* have the chromosome number of $2n=64$. Rollins (1993, page 437), however, wrote about *D. ogilviensis*: "Known only from the Ogilvie Mountains, Yukon, 3000 to 6000 feet".

In 1996 I examined the holotype of *D. ogilviensis*: "Flora of Yukon Territory, Canada, *Draba ogilviensis* Hult. Dempster Highway, NE of Dawson, mile 50, upper N. fork Klondike R., ca 1200 m. Common in meadows below snow flushes, Eric Hultén G-8996 July 15th-21st 1964". Leaves of the type plants of *D. ogilviensis* are glabrous on both lower and upper surface with simple and forked stalked hairs, or more seldom three-four rayed hairs only along margins or leaves totally glabrous; the stems and peduncles are glabrous; the styles are quite long. The life form resembles *D. sibirica*, but another species of *Draba* also has stolons and is totally similar to *D. ogilviensis*: this is *D. juvenilis*. Leaves of this species can be totally glabrous, thin and tender or covered with few rayed hairs but the hairs are always stalked. The appearance of this species is really juvenile: the plants are tender, weak and the leaves are thin. This species is much closer to *D. hirta* L. (*D. glabella* Pursh) than to *D. sibirica*. The variability of petal colour of *D. juvenilis* ranges from whitish-yellowish to yellow. The yellow color was the main basis for one more description: *D. kananaskis* Mulligan which Rollins (1995) referred to the synonymy of *D. longipes*. My study of material of *D. kananaskis* (type: Near snow ridge Ski Resort, 25 mi south of highway 1 on Kananaskis-Coleman Road, about 50 degrees 48'N, 115 degrees 12'W, altitude 7250 ft, G. A. & D. G. Mulligan 3477, Aug. 8, 1969 DAO) made me agree with Rollins' conclusion. The list of synonyms of *D. juvenilis* is as follows: *D. juvenilis* Kom. 1914 Fedde Repert. 13: 167; Tolmachev 1939 Flora of the USSR 8: 429; Tolmachev 1975 Arctic Flora USSR 7: 147.

D. longipes Raup 1934 Contributions of the Gray Herb. 6: 165; Mulligan 1970, Canadian Journal of Botany 48(7): 1434; Porsild 1974 National Museum of Canada Publications in Botany 4: 35.

D. ogilviensis Hultén 1966 Bot. Notic. 119: 315; Mulligan 1976 Canadian Journal of Botany 54(12):1387; Rollins 1993 The Cruciferae of Continental North America: 437.

D. kananaskis Mulligan 1970 Canadian Journal of Botany 48: 1897-1898.

Specimens examined (selected list):

CANADA: Yukon

Ogilvie Mts, river flats along Dempster Rd. Mile 55-56, *R. T. Porsild* 9. Det. A. E. Porsild;

Ogilvie Mts, mountain east of mile 50-54, elev. 5500-5600, *R. T. Porsild*, 141. Det. A. E. Porsild (sub *D. sibirica*, LE);

Dawson Quad, Ogilvie Mountains, North Fork Pass and vic., Dempster Highway, 64°36'N, 132°20'W, herbaceous understorey of tall shrub tundra 1300 m, *Carolyn Parker* 929, 16 June 1984; the same place, *R. Rausch* 16 July 1964; Observation Mountain, ca 24 km SW of Kluane Lake on wet alpine scree slope dominated by *Salix polaris* and *Carex pyrenica*, aspect N, slope 30%, elev. 2188 m, 60°58'N, 138°43'W, *G. W. & G. G. Douglas* Aug. 2/77 Det. G. Mulligan;

310533 Bighorn Creek area, ca 32 km SW of Burwash Landing on moist alpine slope, aspect N, slope 5%, elev. 1980 m, 61 degrees 07' N, 139 degrees 20' W, *G. W. Douglas and L. Freese*, July 23/76 #9993. Det. G. Mulligan (sub *D. ogilviensis* Hult. ALA);

CANADA: Alberta: Herbarium of the University of Alberta Plants of Alberta;

Upper Evans Thomas valley 50°48'N, 115°05'W, in alpine habitat, *Peter Lee*, 14 July, 1980 [label note: *Draba longipes* Raup. Det. by Reed C. Rollins 1986 (sub *D. kananaskis* G. A. Mulligan, DAO, UAC)];

Snow Creek Pass, 30 miles north of Banff, 51°37'N, 115°50'W, *J. A. Calder* 23982B *J. A. Calder* July 26, 1959 (sub *D. longipes* DAO);

Maligne Lake, Jasper Nat. Park (#SJ 7053) alpine tundra, 2340 m, 18° NW *I. Corns*, July 23, 1977, [label note: *Draba longipes* Raup. Det. by Reed C. Rollins (sub *D. kananaskis* G. A. Mulligan. Det. G. A. Mulligan 1978 DAO)];

RUSSIA: Magadan region

Severo-Evensk district, Aulandzha river, mountain creek, gravel, *A. P. Khokhrjakov*, 24 June 1973;

basin of Kegali river, Pravije Imljaki river valley, rocks, *A. P. Khokhrjakov*, 2 August 1976;

Upper Omolon river, Zhdanka river, gravel, *A. P. Khokhrjakov*; 19 June 1980; upper Tachtojama river, *A. N. Berkutenko*, 20 July 1995 (sub *D. juvenilis* Kom. MAG).

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the Herbarium of the Zurich Botanical Garden where I had the opportunity to examine the original samples.

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Daily Departure and Return Patterns of Wolves, *Canis lupus*, from a Den at 80°N Latitude

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We report on daily patterns of Wolf (*Canis lupus*) departures from, and returns to, their den on Ellesmere Island, Northwest Territories, Canada (80°N) during summers between 1988 and 1996. Based on 1759 h of observation, the Wolves departed more often than random during 2200 to 0400 h. There was no darkness during summer, so any sun-based temporal cues must have come from sun position.

Key Words: Wolf, *Canis lupus*, arctic, activity, behavior, circadian rhythm, den, foraging, Northwest Territories.

Wolves generally attend their dens during the day and depart at dusk to forage (Murie 1944; Kolenosky and Johnston 1967; Haber 1977; Ballard et al 1991; Vila et al. 1995; but cf Harrington and Mech 1982). Studies of Wolf departures from den areas have been conducted at latitudes of 42–64°N, where the summer sun dips below the horizon for at least 4 h each night. Thus Wolves might gain temporal cues from this darkness or associated dusk. This evening departure pattern, along with Folk's (1964) finding that, at 70°N where summer light is continuous, captive Wolf circadian day begins at about 2100 h, beg the question as to whether wild Wolves in high latitudes would also depart dens mostly during evening. We tested this question at 80°N where the sun shines continually during the Wolf denning season.

This study was conducted on Ellesmere Island, Northwest Territories, Canada (80°N, 86°W). There, Wolves prey on Arctic Hares (*Lepus arcticus*), Muskoxen (*Ovibos moschatus*), and Peary Caribou (*Rangifer tarandus pearyi*). During 1986, the senior author habituated a pack of Wolves to his presence and reinforced the habituation each summer (Mech 1988, 1995). The Wolf pack frequented the same area each year and generally used the same den (Mech and Packard 1990) or nearby dens (Mech 1993) each summer. The habituation allowed observers to remain with the Wolves each day and observe them regularly.

The senior author and various assistants observed the Ellesmere Wolves around their den during varying periods between 21 June and 4 August 1988,

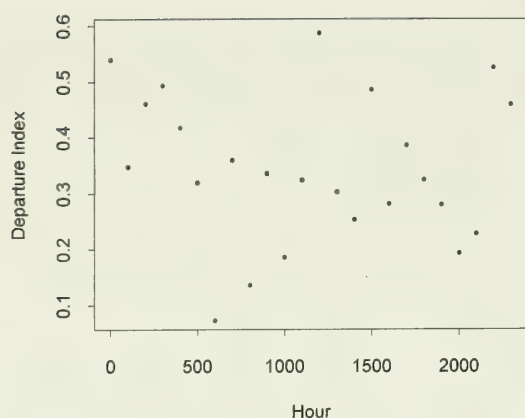


FIGURE 1. Ratio of times Wolves left Ellesmere Island den area each hour divided by number of times observations were made for each hour, based on five summers.

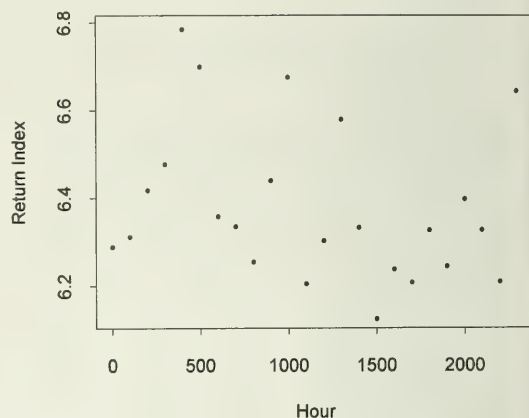


FIGURE 2. Ratio of times Wolves returned to Ellesmere Island den area each hour divided by number of times observations were made for each hour, based on five summers.

1990, 1991, 1994, and 1996 and recorded times of departure from, and returns to, the den for the adult Wolves (including yearlings). We made the observations from distances of 1-100 m away and usually continued to watch the Wolves travel until out of sight at least 1 km away and/or we remained observing the den for at least an hour after departures. Further, we did not count data from excursions known to be food-transport trips from kills < 5 km away because such trips represented exceptions to the usual daily hunting routine. That is, when a large kill was nearby, the Wolves concentrated on making a series of food-transport trips rather than a single long hunting trip. Thus all departures that we included represented daily foraging trips rather than local exploratory jaunts or food-transport trips.

From data forms we tabulated and summed group and individual departures and returns for each hour of the day, and we pooled the data from all years for each hour. Thus we gave group and individual departures the same weight. We adjusted departure and return data for hours of observation by summing the number of days each year the den was observed at each hour, and multiplying the number of observed departures and returns per hour by 1/this number. For example, if four departures were recorded between all 2000-2100-h periods in a given year, and we observed during this period 20 times that year, the adjusted value was $4/20 = 0.2$.

We then pooled adjusted departures and returns for the five observation years and tested them by ANOVA against the following 6-h periods: 2200-0359, 0400-0959, 1000-1559, and 1600-2159 h to test the hypothesis that Wolves leave their den late in the day and return to their den at random times. We chose these periods because field observations sug-

gested that this manner of pooling hours would be most likely to detect differences in times of Wolf departures and returns. ANOVA models were checked for normality of residuals.

We recorded observations of Wolf departure and return rates for 1759 hours (mean = 293 per summer) over 153 days (mean = 31 per summer) during the five summers of the study. Six different Wolves were involved, two of which were present for all five summers; one female was a non-breeder during one of those years and a breeder during the remaining four, and one was a breeder during 1 year and non-breeder during her remaining 2 years (Mech 1995, and unpublished).

We observed significantly fewer group and individual departures (180) than group and individual returns (230) (t test, $P < 0.001$). As members of groups split up while foraging, individuals then tended to return separately, thus resulting in the greater number of returns.

The Wolves departed from the den area at all times of day, but like Wolves at lower latitudes, they tended to leave dens on foraging trips more often during late evening and early morning, starting about 2200 h (Figure 1). They left least frequently on average from 1600-2200 h. This pattern differs significantly from random ($F_{3,20} = 3.95$, $P = 0.02$). The Wolves tended to return to the den least often during 1600 to 2000 h (Figure 2).

Kolenosky and Johnston (1967) found that one of two peak den-leaving periods for Wolves at 46°N began around 2100 h. At 64°N , Wolves left dens between 1600 and 2200 h (Murie 1944), and starting around 2200 hr (Haber 1977). Ballard et al. (1991) reported Wolf departures at 63°N most frequent from 2100 to 2400 h (27% of 191 observations) and least

frequent from 1300 to 2100 h, as we did. In Spain, at about 42°N, general Wolf activity and activity around dens peaked at about 2100 h and 0500 h (Vila and Castroviejo 1995). Presumably it is this basic circadian activity pattern (Folk 1964) that leads to Wolves departing from the den during evening.

In a Minnesota study (48°N) involving two dens, Wolves did not tend to leave the den area more during late evening but rather left most often around dawn (Harrington and Mech 1982). These contrasting results are puzzling, especially in view of the Ontario study at about the same latitude and the same type of forested habitat (Kolenosky and Johnston 1967).

In any case, our study indicates that regardless of latitude and amount of sun each day, Wolves tend to depart from dens at about the same time daily. Contrary to the Wolves in previous studies, our Wolves could not have obtained temporal cues from darkness, for there was no darkness in our area during the study or for many weeks before. The sun does dip toward the north at midnight and reaches its zenith in the south around midday, so we suggest that our Wolves might be gaining their temporal cues from sun position, as Folk (1964) also suggested.

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Evidence of Spring Staging and Migration Route of Individual Breeding Harlequin Ducks, *Histrionicus histrionicus*, in Southern British Columbia

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Wright, Kenneth G., Gregory J. Robertson, and R. Ian Goudie. 1998. Evidence of spring staging and migration route of individual breeding Harlequin Ducks, *Histrionicus histrionicus*, in southern British Columbia. *Canadian Field-Naturalist* 112(3): 518–519.

An individually marked pair of Harlequin Ducks (*Histrionicus histrionicus*) were observed on moulting and spring staging and the male also on breeding grounds in southern British Columbia.

Key Words: Harlequin Duck, *Histrionicus histrionicus*, spring staging, migration.

Little is known of the migratory and staging behaviour of the Harlequin Duck (*Histrionicus histrionicus*). Palmer (1976) stated that birds form spring assemblies on coastal areas nearest to their inland nesting sites. However, little is known about the moulting/wintering and breeding movements and likely migratory routes of these individuals. In this paper we describe the movement of a male Harlequin Duck and his mate over the annual cycle.

During the past four years, over 2000 Harlequin Ducks have been banded in coastal British Columbia, mostly in the Strait of Georgia (49°40' N, 124°54' W). Using a team of six kayakers and a drive trap set up on shore at low tide, the birds were driven into the trap (Clarkson and Goudie 1994). Birds were captured during the moulting period in August–September when they are in flightless condition. All birds were fitted with standard aluminum U.S. Fish and Wildlife Service bands and an alpha-numeric colour band on the opposite leg. The latter band facilitates resighting with a 20–60 × spotting scope. Birds were sexed and assigned to an age-category by plumage characteristics and cloacal examination, respectively.

The drake (green "P2") was initially captured on the northeast side of Hornby Island (Figure 1) 3 August 1994 as a flightless adult (after-third-year). This drake was subsequently observed 2 km southeast of its moulting location on Hornby Island on 29 August 1994 with his primaries grown back in (S. Boyd, personal communication). During the annual Pacific Herring (*Clupea harengus*) spawn in spring of 1995 the drake was re-observed on Hornby Island among approximately 4000 Harlequin Ducks (Canadian Wildlife Service, unpublished data). On 19 August 1995 he was recaptured as a flightless bird again. This time, however, he was captured at Cape Lazo near Comox on Vancouver Island, 24 km northwest of Hornby Island. On 10 April 1996 the drake was sighted at Lily Point, Point Roberts, Washington,

paired to a banded female (green "98") about 150 km southeast of Cape Lazo (GJR). This female was initially captured on 19 August 1995 at Cape Lazo in the same banding drive as her mate (P2).

While conducting a breeding survey of Harlequin Ducks in the British Columbia interior, P2 was observed on the Ashnola River (elevation 470 m) on 16 May 1996 approximately 1.6 km upstream of the Similkameen River (250 km due east of Lily Point). He was alone loafing on a mid-stream cobble (KGW). The breeding habitat of the Ashnola River is characterized by semi-arid conditions which would support early nesting, so it is not unrealistic that the female would have started incubation by 16 May, most likely explaining why the male was alone.

This is the first documented occurrence of a known individual breeding pair of Harlequin Ducks staging prior to their breeding migration. Lily Point supports a somewhat discrete moulting and wintering population of 40–80 ducks, and is the first area of suitable Harlequin Duck habitat south of the Fraser River delta. There are number of banded Harlequin Ducks that are only seen during April at Point Roberts (GJR, unpublished data). Lily Point is a likely staging site given its proximity to the Fraser River Delta. The Fraser River would be a suitable migration corridor for Harlequin Ducks due to its east-west orientation.

These observations suggest that Harlequin Ducks do not migrate to their breeding area in one nonstop migration. Instead, they make a coastal migration to a site near their breeding grounds, later migrating to the interior. Harlequin Ducks in Iceland nest close to their coastal wintering grounds and in those populations the ducks simply swim or make short flights up the rivers to their breeding areas (Bengtson 1966). Nothing has been postulated regarding the migratory nature of Harlequin Ducks in North America where mountain ranges may pose a potential barrier. In this case, the pair observed would have to cross the

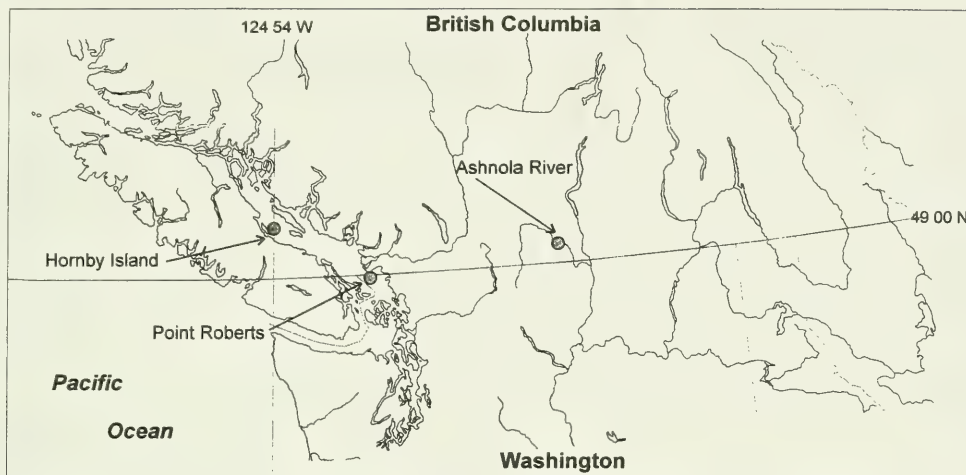


FIGURE 1. Moulting, spring staging, and breeding locations of two banded Harlequin Ducks in British Columbia.

Cascade Mountain Range at a minimum altitude of 1340 m. This hypothetical route would involve crossing one mountain pass and then descending into the upper Similkameen River. The only alternative routes that would not involve crossing mountains are the Columbia River Valley, which originates some 500 km to the south, or the Fraser-Thompson-Nicola route to the north. Harlequin Ducks nesting on the east side of the continental divide certainly migrate overland at least once during each migration.

Common Eiders spend the most amount of time in marine waters of all sea ducks, yet they too have been seen to migrate overland, sometimes at very high altitudes (Gauthier et al. 1976). Furthermore, Erskine (1964) suggested that many species of birds, including sea ducks, migrate over the Coast Mountains of British Columbia when favourable wind conditions presented themselves. Therefore, it is not unlikely that Harlequin Ducks regularly undertake higher altitude migration routes that cross major mountain ranges en route to breeding grounds.

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Displacement of a Large Double-crested Cormorant, *Phalacrocorax auritus*, Colony Following Human Disturbance

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Cairns, D. K., R. L. Dibblee, and P.-Y. Daoust. 1998. Displacement of a large Double-crested Cormorant, *Phalacrocorax auritus*, colony following human disturbance. *Canadian Field-Naturalist* 112(3): 520–522.

Double-crested Cormorants (*Phalacrocorax auritus*) breeding at a Prince Edward Island colony, the largest in northeastern North America, shifted their nesting location to a nearby island after springtime shooting at the colony. Post-shift numbers at the new site (4525 nests) were 92% of the previous combined population of the two colonies. Clutch size and hatching date were similar before and after the move. Disturbance-induced displacements of seabird colonies are rare; this shift may have been caused by perturbation during a sensitive period prior to laying.

Key Words: Seabirds, Double-crested Cormorant, *Phalacrocorax auritus*, disturbance, colony displacement, Prince Edward Island.

Seabirds are philopatric animals that usually return to their natal colonies to breed and rarely shift sites after first breeding (Aebischer 1995; Harris et al. 1996). Even when breeding sites are destroyed, birds that bred there in previous years often attend the former colony throughout the reproductive season (Southern and Southern 1982; Fairweather and Coulson 1995). Only terns, skimmers, and some gulls that nest in ephemeral habitat such as sand bars and marsh islands commonly shift breeding locations (Evans 1982; Cuthbert 1988; Siegel-Causey and Kharitonov 1990).

Double-crested Cormorants, *Phalacrocorax auritus*, exhibit the typical seabird pattern of strong philopatry and site-fidelity (Siegel-Causey and Hunt 1986). This note reports an atypical displacement of a large colony following human disturbance.

Double-crested Cormorants have bred in Malpeque Bay, Prince Edward Island, at least since the early 1980s. The tree-nesting colony on Ram Island (46°32'N, 63°45'W), with 4517 nests, held 68% of Prince Edward Island's breeding population (1995 figures) and was the largest cormorant colony in northeastern North America (Figures 1 and 2) (Lock et al. 1994; Krohn et al. 1995). Although nearly all trees on this island have been killed by cormorant activity, most remain standing. Several hundred pairs of Double-crested Cormorants have also bred on Little Courtin Island, 3 km to the south of Ram Island, since 1987 (Figure 2). This treeless island (actually two islets) is scarcely above the high tide mark; in June 1992, storm-driven seas swept it clean of cormorant and Herring Gull, *Larus argentatus*, nests and nestlings.

On 15 May 1996, when the Ram Island colony would normally be in its incubation stage, no cor-

morants were found on the island. On 22 May, all coastlines and islands of west-central Prince Edward Island were searched by helicopter. No new breeding sites were located, but the colony at Little Courtin Island had greatly expanded. A ground census there on 7 June recorded 4525 nests, which is 92% of the combined total for Ram (4517) and Little Courtin (424) during the previous year. It is thus evident that birds from the Ram Island colony shifted to Little Courtin Island in 1996.

The abandonment of Ram Island and the shift to Little Courtin was apparently brought about by shooting and harassment at the colony in spring 1996. Local reports of shooting on the island were confirmed by the discovery of cormorant carcasses in the nesting area. Dates of the shooting are unknown, but must have occurred between late April, when cormorants return to the area, and the visit of 15 May.

In 1997, Ram Island was re-colonized, presumably by birds from Little Courtin Island. The re-established colony contained 1738 nests, while the Little Courtin population fell by 1549 nests to 2976 (Figure 2).

The shift to Little Courtin was not accompanied by reproductive impairment, as mean clutch size and hatching dates were similar in Ram Island (1994 and 1995) and Little Courtin (1996 and 1997) (Table 1). Hatching and nestling success were not compared because nests could not be followed on Little Courtin without exposing eggs and young to gull predation.

Despite legal protection, harassment at Double-crested Cormorant colonies remains common (Duffy 1995). Lewis (1929) reported that colonies subject to continued harassment tended gradually to shrink in

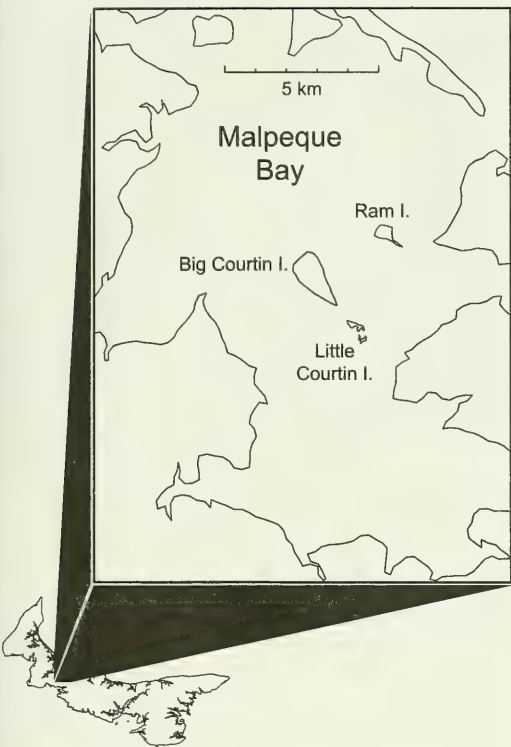


FIGURE 1. Malpeque Bay, Prince Edward Island.

population, with some, but not all, birds apparently shifting to other breeding sites. This pattern continues to apply in Maritimes and Quebec colonies (personal observation; personal communications from G. R. Milton, Nova Scotia Department of Natural Resources and G. Chapdelaine, A. J. Erskine, and A. R. Lock, Canadian Wildlife Service). In Lake Ontario, most cormorants continued to attend a colony which was subject to shooting during the breeding season, although surviving birds suffered a sharp decrease in nest productivity (Ewins and Weseloh 1994).

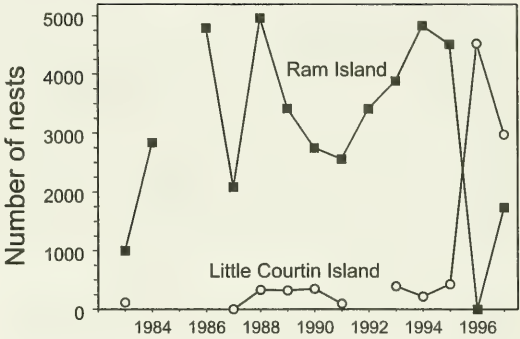


FIGURE 2. Double-crested Cormorant populations on Ram and Little Courtin islands, Prince Edward Island. No censuses were conducted in years where symbols are absent.

In Maine, cormorants generally persist in breeding at harassed colonies, but several colonies have recently changed nesting islands following seasons in which Bald Eagles, *Haliaeetus leucocephalus*, established nearby nests and regularly raided cormorant breeding sites (R. B. Allen, personal communication). Fear of eagle predation did not figure in the shift of Ram Island cormorants to Little Courtin, as a Bald Eagle nest at the southeast tip of Big Courtin Island is < 1 km from the new breeding site (Figure 1). Complete destruction of reproductive effort by a storm can also induce a colony shift (Lewis 1929) (although birds at Little Courtin returned to breed in 1993 after the 1992 storm which destroyed their nests).

The displacement of the large Ram Island Double-crested Cormorant colony following human disturbance therefore remains anomalous. We hypothesize that the disturbance may have occurred during a window of sensitivity when birds were selecting nest sites, and prior to clutch initiation which would have cemented their ties to Ram Island. The colony on nearby Little Courtin Island may have acted as an attractant, providing the kernel around which the displaced birds nested (Cairns and Elliot 1987; Buckley and Downer 1992).

TABLE 1. Reproductive parameters of Double-crested Cormorants on Ram and Little Courtin islands.

	Clutch size		Hatching success (chicks hatched per egg laid)		Nesting success (chicks surviving to > 28 d/chicks hatched)		Hatching date	
	Mean	N	Mean	N	Mean	N	Mean	N
Ram Island								
1994	3.27	93	0.69	304	0.71	209	9 June	10
1995	3.22	83	0.59	268	0.71	173	7 June	64
Little Courtin Island								
1996	3.20	39	NA		NA		6 June	61
1997	3.55	101	NA		NA		10 June	95

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Visitation of the Endemic Dwarf Lake Iris, *Iris lacustris*, by Halictid Bees, *Augochlorella striata*

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Larson, Brendon M. H. 1998. Visitation of the endemic Dwarf Lake Iris, *Iris lacustris*, by halictid bees, *Augochlorella striata*. *Canadian Field-Naturalist* 112(3): 522–524.

Insect visitors to the endemic the endemic Dwarf Lake Iris (*Iris lacustris*) have not previously been reported. Halictid bees (*Augochlorella striata*) were observed visiting *I. lacustris* at Dorcas Bay, Bruce Peninsula, Ontario, in late May 1996. Their floral visitation and grooming behaviours suggest that they are potential pollinators.

Key Words: halictid bees, *Augochlorella striata*, flower visitation, Dwarf Lake Iris, *Iris lacustris*, pollinators.

Dwarf Lake Iris, *Iris lacustris* (Iridaceae), is a narrow endemic that is largely restricted to the northern shores of Lakes Huron and Michigan in Ontario, Michigan, and Wisconsin (Guire and Voss 1963). It is often locally abundant, but because of its restricted range and habitat, and intense development pressures on shorelines, it is considered rare to uncommon globally and in Ontario (Bruce and Manitoulin Counties), Michigan, and Wisconsin (Argus and Pryer 1990; Oldham 1996). In Canada, it is listed

among the rare plant species deserving highest conservation priority (Priority 1 of Argus and Pryer 1990). Despite investigation of the breeding system and other aspects of the biology of *I. lacustris*, its pollinators have not yet been observed (Planisek 1983; Van Kley and Wujek 1993). This ignorance is significant because knowledge of its pollination biology may provide insight into factors limiting its fecundity (e.g., Planisek 1983) and genetic variation (e.g., Simonich and Morgan 1994). In this note, I

report visitation of *I. lacustris* by halictid bees on Ontario's Bruce Peninsula in 1996.

Iris lacustris has showy flowers that bloom from mid-May to early June. They consist of three independent pollination units (see Figure 1 in Kron et al. 1993), each composed of a dorsal petaloid style and a ventral sepal that form a tube enclosing the anther. The stigmatic surface is located on the upper side of a flap on the ventral surface of the petaloid style. *Iris lacustris* is self-compatible, but autonomous self-pollination only accounts for about one-third of open-pollinated fruit set (G. Hannan, personal communication; and see Kron et al. 1993; Zink and Wheelwright 1997 for potential mechanisms). Therefore, most pollination occurs when insects carrying pollen crawl between the petaloid style and the sepal, and deposit pollen on the stigma.

In the early afternoon on 25 May 1996, halictid bees (*Augochlorella striata*) (voucher specimen deposited at the Royal Ontario Museum) were observed visiting a few local patches of *I. lacustris* on an open shoreline at Dorcas Bay (81°35' W, 45°11' N). As many as two bees visited flowers concurrently, and they spent up to one minute within individual pollination units, presumably collecting nectar and possibly pollen. The bees crawled between the sepal and petaloid style until their abdomen was entirely hidden and at the level of the stigma flap, a position that could allow pollen removal and deposition. Lengthy visits in this position suggest that the bees may often facilitate self-pollination within pollination units (G. Hannan, personal communication). They regularly moved between pollination units and from flower to flower, suggesting that pollen transfer is likely and that self-pollination (pollen transfer between pollination units, flowers on a plant or plants in a clone) may be frequent. The bees also groomed pollen intensely, often when perched at the flower's centre. From this central position, they sometimes "cheated" by entering the base of pollination units sideways, such that the style could not be contacted.

Augochlorella striata is an abundant and widely distributed halictid bee in Ontario (Knerer and Atwood 1962) that is a common polylectic flower visitor (numerous plant genera, but not *Iris*, listed in Mitchell 1960; Knerer and Atwood 1962). It was considered the major pollinator of Shining Ladies'-tresses (*Spiranthes lucida*) on the southern Bruce Peninsula (Catling 1983), and has also been observed visiting two other prevalent spring flowers on Bruce Peninsula shorelines, Bird's-eye Primrose (*Primula mistassinica*) (Larson and Barrett in press a) and Bluets (*Hedyotis longifolia*) (Larson and Barrett in press b). It was frequent to occasional on the flowers of several Ottawa weeds (Mulligan and Kevan 1973), and lastly, in Muskoka it has been observed "buzzing" (sensu Buchmann 1983) individ-

ual anthers of Virginia Meadow Beauty (*Rhexia virginica*) (personal observation). These observations suggest that its relationship to *I. lacustris* is not highly specialized.

Intensive observational studies are required to determine whether *A. striata* is the predominant pollinator of *I. lacustris*. Given the commonness of this bee, it is surprising that it has not been observed at these flowers before, but visitation during late May may be quite stochastic and weather-dependent. Fruit-set in the Dorcas Bay population in 1996 was extremely low, so future research should also investigate the degree of pollen limitation and modes of self-fertilization (e.g., Lloyd and Schoen 1992) in Ontario populations of this species, to ascertain the relative contribution of low pollinator visitation and inbreeding depression to limited fecundity. Further investigation of pollination and factors limiting reproductive success in *I. lacustris* may facilitate effective management and conservation of shoreline populations.

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First Nest Record of Northern Hawk Owl, *Surnia ulula*, in Nova Scotia

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Two families and one additional pair of Northern Hawk Owls, *Surnia ulula* (L.) were discovered in the core of the Cape Breton Highlands National Park during an expedition in the summer of 1996. They were found in woods defoliated by Spruce Budworm (*Choristoneura fumiferana*). This defoliation and the resulting opening up of the woods may have enticed the Hawk Owls to expand their breeding range into Nova Scotia; alternatively, the rather remoteness of the site may have prevented their previous discovery.

Key Words: Northern Hawk Owl, *Surnia ulula*, Cape Breton Highlands National Park.

In June and July of 1996, we conducted a field study in a remote part of Nova Scotia's Cape Breton Highlands National Park. The objective was to document the presence of several rare species of animals and plants in that area. The avifaunal component of the project included ten target species (see appendix), some of which were sporadically known from the Highlands, whereas others like the Northern Hawk Owl had never been recorded as breeders. The Northern Hawk Owl is a holarctic species known to breed in a variety of more open areas of the boreal forest. It does not breed in Prince Edward Island and is only an occasional breeder in New Brunswick (Erskine 1992); Godfrey (1986) shows its nesting range to include Newfoundland. In recent decades, there have been sporadic summer sightings in Nova Scotia, though no reports of breeding (Tufts 1986).

Study Site and Habitat

Cape Breton Highlands National Park is located in the extreme north of Cape Breton Island. Much of the study site (centered at 46° 42' N, 60° 40' W) is dominated by fairly large areas of open forest with

most of the mature Balsam Fir (*Abies balsamea*) and spruces (*Picea* spp.) killed by Spruce Budworm (*Choristoneura fumiferana*) infestation in the 1970s and early 1980s (Anonymous 1980; Pech 1993); many of the snags have fallen but the majority remain standing. Remnant stands of mature White Birch (*Betula papyrifera*) pocket these budworm-killed areas. The younger birches are severely stunted in growth due to the heavy browsing by Moose (*Alces alces*). The forest has recovered somewhat, especially in the wet areas, where it is growing up in alders (*Alnus* spp.) and sedges (*Carex* spp.). In the drier areas, low shrubs (e.g., *Rubus* spp.), White Birch and a thick cover of grasses predominated.

The lush understorey, released by opening of the canopy due to the budworm infestation, provides dense cover for an abundance of small mammals, which themselves would be ample food for the Hawk Owls (Figure 1). The search for rarer small mammals formed another component of the overall project; this was done by laying out lines of snap traps. This component of the work also allowed us to survey the types of small mammals in this habitat,

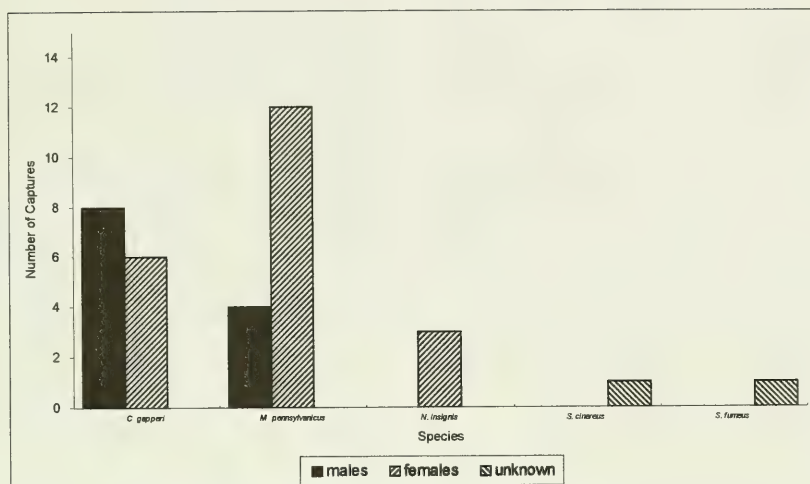


FIGURE 1. The captures of small mammals from 184 trap-nights.

and their relative abundances. Trapping success was quite high, almost 20% (35 animals, 184 trap nights; Figure 1), with Meadow Voles (*Microtus pennsylvanicus*) being the most abundant (46% of all captures). Other captures, in order of decreasing abundance were Red-backed Vole, *Clethrionomys gapperi*; Woodland Jumping Mouse, *Napaeozapus insignis*; Masked Shrew, *Sorex cinereus*, and Smoky Shrew, *S. fumeus* (Figure 1).

Breeding Evidence

We came across the first Northern Hawk Owl opportunistically, alerted to its presence by its vocalization. Upon returning to the site, we again found the bird and were able to spend time observing it. On two occasions (separated by about 20 min) the bird caught a prey item (likely *M. pennsylvanicus*) and flew directly away from the foraging area. Upon capturing prey intended for its mate or young, male Hawk Owls are known to make a rapid, direct return to the nest (Jones 1987). We took a bearing on the bird's direction and started to track it to what we assumed was a nest site. Vocalization of what was initially believed to be nestlings aided in the detection of the nest. The calls were actually those of the attending adult who greeted her mate on each arrival. The habitat at the nest site was identical to that of the previously described foraging site. With both adults present and showing aggression (bill-snapping, interception-flying) locating the nest tree was relatively easy.

The nest was in a conifer snag (dbh = 0.25 m) broken off at a height of 9 m. The base of the cavity (i.e. the height of the nest) was 6 m from the ground and continued to the top; much of the interior of the nest was exposed from the level of the nest to the top of the tree (i.e. a chimney-style cavity with half of the

wall missing). As a result, the young owls were visible, though only as an amorphous mass of grey down with some flight feathers emerging. As we did not want to disturb the birds unnecessarily, an exact count of the young was not obtained.

On our second visit, in July, we found a group of four fledglings accompanied by a single adult in a different section of the study site, approximately 2 km northwest of the first nest site. A third pair of owls was seen in yet another tract of woods, again in the familiar open habitat; we had no time to assess that pair's breeding status.

Discussion

For the most part, nineteenth century authors claim the Northern Hawk Owl to be an uncommon, winter bird (Downs 1888; Piers 1892, 1894, 1897); only Jones (1879) claimed that it was not uncommon throughout the year.

New nesting records have been recorded from the western portion of the nearctic range of the Northern Hawk Owl (Gniadek, Holt and Wright 1997). Those authors did not presume that their new nest records were a result of range expansion; rather they suggested that a lack of effort has kept the Hawk Owl's breeding status a mystery. While surveying for the Atlas of Breeding Birds of the Maritime Provinces, a number of individuals were able to search pertinent areas of the Cape Breton Highlands (albeit all too briefly), but no Hawk Owls were seen (Erskine 1992). Only one family group was found in all of the Maritimes (that one being in New Brunswick). The Hawk Owl is not a cryptic bird (it is large, diurnal, vociferous and perches very conspicuously on tree-tops), so not finding it in a searched area may mean that it is really not there. This is in marked contrast to the small, nocturnal and essentially quiet Boreal Owl

(*Aegolius funereus*) whose presence has been established over several years in the Cape Breton Highlands, but has never been proven to breed. We documented the first summer sighting of Boreal Owls in Nova Scotia during this same expedition, but found no further evidence of breeding (Lauff, Brennan and Miller 1997*). The recent habitat change which resulted from a high point in the Spruce Budworm cycle, makes it tempting to believe that the Northern Hawk Owl (unlike the Boreal Owl) is a recent arrival or perhaps a periodic and opportunistic breeder in the province. However, with the lack of qualified observers visiting this area in the past, its former breeding status may remain unknown.

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Appendix: The ten birds targeted on this expedition.

Species	Notes
Golden Eagle (<i>Aquila chrysaetos</i>)	immature, one sighting
Greater Yellowlegs (<i>Tringa melanoleuca</i>)	courtship displays, agitated behaviour
Solitary Sandpiper (<i>Tringa solitaria</i>)	one sighting
Least Sandpiper (<i>Calidris minutilla</i>)	courtship displays
Northern Hawk Owl (<i>Surnia ulula</i>)	nest, fledged young
Boreal Owl (<i>Aegolius funereus</i>)	repeated sightings in same area over 2 months
Northern Three-toed Woodpecker (<i>Picoides tridactylus</i>)	not found
Bicknell's Thrush (<i>Catharus bicknelli</i>)	repeated sightings
American Tree Sparrow (<i>Spizella arborea</i>)	not found
Common Redpoll (<i>Carduelis flammea</i>)	not found

Captures of Mice, *Peromyscus*, in Two Sizes of Sherman Live Traps

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We tested two different-sized Sherman live traps for their effectiveness in capturing small mammals. Significantly more White-footed Mice (*Peromyscus leucopus*) and Cotton Mice (*P. gossypinus*) were captured in small traps. Significantly more Rice Rats (*Oryzomys palustris*) were captured in large traps. Mean body mass of individual *Peromyscus* captured in small versus large Sherman traps did not differ significantly. Mortality was negligible in both sizes of trap.

Key Words: live trapping, Sherman trap, small mammals, White-footed Mouse, *Peromyscus leucopus*, Cotton Mouse, *P. gossypinus*, Rice Rat, *Oryzomys palustris*.

Previous investigators have compared different trap types and sizes for sampling small mammals and have found a variety of factors that influence the number of individuals and taxa captured. For example, Wiener and Smith (1972), Duran and Samz (1973), Pendleton and Davison (1982), and Woodman et al. (1996) found that snap traps caught more small mammals than did live traps. Cockrum (1947), Sealander and James (1958), Hansson and Hoffmeyer (1973), and Rana (1982) found the opposite, whereas Pelikan et al. (1977) indicated no significant difference in capture success rate between live versus snap traps. Response of small mammals to live and snap traps often is species-specific (Balkcom et al. 1996).

Several different types of small mammal live traps have been compared for relative efficiency. Morris (1968) found Sherman traps, commonly used in the United States, were more effective than Longworth traps. Other investigators have found, however, that alternative types of live trap are more effective than Sherman traps (Holdenried 1954; Rose et al. 1977; O'Farrell et al. 1994).

Different sizes of Sherman live trap also have been compared. Slade et al. (1993) found that Sherman traps 30.5 cm long (model LGN12) had more small mammal captures with a lower mortality rate than Sherman traps 22.9 cm long (model LFG). Quast and Howard (1953) found greater numbers of rodents were captured in large Sherman traps (model 3310A; 7.6 × 7.6 × 25.4 cm) than in small Sherman traps (model SFA; 5.1 × 6.4 × 16.5 cm). In contrast, Dalby and Straney (1976), without indicating specific trap sizes, found small Sherman traps captured significantly more White-footed Mice (*Peromyscus leucopus*), and greater numbers of less-common species, than did large Sherman traps. Other studies (Kiesel 1972; Maly and Cranford 1985) have found no difference in small mammal captures related to size of Sherman traps. Our objectives were to investigate trap size on capture rate of small mammals, and also to test whether body mass was a factor in trap selection. Specifically, we tested whether:

(1) large and small Sherman live traps were equally effective in capturing small mammals in study areas located in bottomland hardwood forest habitat of southern Illinois; and (2) whether individuals of lower body mass were taken more often in small traps, larger individuals in large traps.

Methods and Materials

Livetrapping for small mammals was conducted in July, August, and September 1996, as part of a larger investigation on 22 sites throughout Horseshoe Lake Conservation Area (HLCA), Alexander County, Illinois (approximately 37°07' N, 89°20' W). Located in the Mississippi River floodplain, HLCA encompasses 3702 ha of bottomland forest, emergent wetlands, and swamps.

On 20 sites, traps were set in 90-m-long transects with 10 stations each 10 m apart. We set one large Sherman live trap (primarily nonfolding model LNA, but also folding model LFA; both were 8 × 9 × 23.5 cm) and one small, nonfolding Sherman live trap (model SNA; 5.4 × 6.3 × 16.5 cm) at each station. Traps were baited with cracked corn and sunflower seeds and were operated for three consecutive days each month. Traps were not prebaited. Captured animals were toe-clipped, weighed to the nearest 0.5 g, and released at the point of capture. Variable numbers of large and small Sherman live traps were also operated for three consecutive days at two additional sites at HLCA during the same period.

Once an animal was captured at a station, a second individual no longer had a choice of traps at that station. Because we could not determine which trap at a station was occupied first, capture data were analyzed using Chi-square tests after eliminating from consideration all stations where both traps were occupied.

Results

A total of 4950 trap nights resulted in 1006 captures of six small mammal species. Two species comprised 961 (95.5%) of the captures. These were White-footed Mice (95.2% of all captures) and

TABLE 1. Captures of small mammals in small and large Sherman traps on 22 sites at Horseshoe Lake Conservation Area, Alexander County, Illinois.

Taxon	Total Captures		χ^2 -value	P
	Small Trap	Large Trap		
<i>Peromyscus</i> spp.	380	275	16.83	< 0.001
<i>Oryzomys palustris</i>	6	15	3.86	< 0.05

Cotton Mice (*P. gossypinus* — 0.3% of all captures) which we grouped together for analyses. The only other species captured in large enough numbers for analysis was the Rice Rat (*Oryzomys palustris* — 2.1% of captures). Eliminating all records at stations where both the large and small Sherman traps were occupied resulted in a data base of 655 capture records of both species of *Peromyscus*.

Small Sherman live traps captured significantly more *Peromyscus* and significantly fewer *O. palustris* than expected (Table 1). Mortality was not a factor in our study as only two (0.3%) *Peromyscus* and no Rice Rats died in the traps.

Considering only *Peromyscus*, there were significantly more males captured ($n = 372$) than females ($n = 283$) in all traps ($\chi^2 = 12.09$, $P < 0.001$). The sex ratio for the two sizes of trap was 1.25 males per female in the small traps and 1.41 males per female in the large traps. Both sexes were taken significantly more often in small traps than large traps (Table 2).

Mean body mass of male *Peromyscus* captured in small traps ($\bar{x} = 20.7$ g; $SD = 3.9$) was not significantly different ($t = 0.762$; $df = 129$; $P = 0.45$) from the mean body mass of males in large traps ($\bar{x} = 21.2$ g; $SD = 3.0$). Likewise, there was no difference in body mass of female *Peromyscus* in small ($\bar{x} = 18.8$ g; $SD = 2.9$) versus large traps ($\bar{x} = 18.9$ g; $SD = 2.7$; $t = 0.190$; $df = 63$; $P = 0.85$). Combining all captures regardless of sex, there was no significant difference in mean body mass of *Peromyscus* in small ($\bar{x} = 20.1$ g; $SD = 3.7$) versus large ($\bar{x} = 20.4$ g; $SD = 3.1$; $t = 0.569$; $df = 194$; $P = 0.570$) traps.

Discussion

Like Dalby and Straney (1976), we caught significantly more *Peromyscus* in small than in large Sherman traps. Based on a qualitative evaluation, they concluded that the difference in capture results may have been related to treadle and/or spring sensitivity. They did not analyze mean body mass of captured individuals, however. Based on our results, we conclude that body mass and associated trap sensitivity was not a factor in capture rates. Instead, we suggest that a different behavioral response of *Peromyscus* to large versus small Sherman traps is a more plausible explanation. In general, the two species of *Peromyscus* in our study probably favored

TABLE 2. Captures of male and female *Peromyscus* spp. in small and large Sherman traps on 22 sites at Horseshoe Lake Conservation Area, Alexander County, Illinois.

Sex	Total Captures		χ^2 -value	P
	Small Trap	Large Trap		
males	211	161	6.72	< 0.01
females	169	114	10.69	< 0.005

small traps because of a mosaic of intrinsic factors in addition to behavior, as well as population density, demographics, habitat, seasonality, and other site-specific extrinsic factors.

Maly and Cranford (1985) found no significant difference in captures of *Peromyscus leucopus* in small versus large Sherman traps. They also questioned the conclusion of Dalby and Straney (1976) concerning trap sensitivity because they captured similar numbers of Least Shrews (*Cryptotis parva*), with a mean body mass of 4.1 g, in both sizes of trap. Likewise, for our study, we considered the lightest 10% of *Peromyscus* captured in each size of trap, a range of 11 to 16 g. There was no significant difference between trap sizes in the mean body mass of the lightest individuals captured ($t = 1.06$; $df = 29$; $P = 0.30$). Like Maly and Cranford (1985), however, we found the largest species, Rice Rats, was taken most often in the larger traps. As suggested by Slade et al. (1993), a combination of trap types probably is most effective for sampling diverse small mammal faunas, although this approach makes comparisons among studies difficult.

Interestingly, when we analyzed our data without deleting those stations in which both traps were occupied, all results were the same. It could be argued that the second individual at the station did in fact have a choice, the choice being whether or not to enter the trap. Of course, we do not know how many individuals chose not to enter either the large or small trap at a station. Likewise, we do not know whether prebaiting traps would have changed our results. We strongly suspect that the results would be the same regardless of prebaiting. Bait was available throughout trapping; an additional day of bait availability should have no influence as the small mammal species in our study apparently keyed on trap size.

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Distraction Displays Made by Female Common Eiders, *Somateria mollissima borealis*, in Response to Human Disturbance

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Kay, Maureen F., and H. Grant Gilchrist. 1998. Distraction displays made by female Common Eiders, *Somateria mollissima borealis*, in response to human disturbance. *Canadian Field-Naturalist* 112(3): 529–532.

A high frequency of distraction displays was observed among Common Eiders (*Somateria mollissima borealis*) nesting on an island in East Bay, Southampton Island, Northwest Territories. Although this anti-predator behavior is common among ground-nesting birds, it appears to be rare among Common Eiders. This may be because Common Eiders nest on offshore islands where terrestrial predators are limited and/or because this type of behaviour increases the risk of predation for the female. Eiders at the East Bay colony, however, are subjected to Arctic Foxes (*Alopex lagopus*) during egg-laying and early incubation and this may have influenced the frequency with which distraction display behaviors are expressed.

Key Words: Common Eider, *Somateria mollissima borealis*, distraction display, predator, human disturbance, Northwest Territories.

Many breeding birds use distraction displays such as feigning injury to lure predators towards themselves and away from their nest or young (Barash 1975; Mallory and Weatherhead 1993; Burger and Gochfeld 1994). This behavior, which can be a risk to the parent, is thought to be an evolutionary response that increases the fitness of the parent by improving the survival of offspring (Barash 1975). A

trade-off exists, therefore, between risk of death for the parent and enhancement of survival for the offspring (Andersson et al. 1980). In theory, this trade-off is influenced by the fitness value of the clutch, expected lifetime reproductive success of the parent, and the age of the parent (Mallory and Weatherhead 1993; Forbes et al. 1994). The optimal degree of nest defence for an individual may also vary with the vul-

nerability of the nest, the ability of the parent to escape predator attack, and predator foraging behavior (Gochfeld 1984).

Distraction displays are most common among ground-nesting birds in open habitats, where eggs and young are vulnerable to mammalian predators (Armstrong 1965; Simmons 1955). Common Eiders (*Somateria mollissima*) nest on the ground, and their eggs and young are often vulnerable to both avian and mammalian predators (Quinlan and Lehnhausen 1982; Gotmark and Ahlund 1988; Robertson 1995). Despite this, distraction display behavior among Common Eiders is considered rare (Williamson 1948; Swennen 1968; Stehn et al. 1993). Common Eider females typically flush from their nests and simply fly to water when approached by humans (Gotmark and Ahlund 1984), or Arctic Foxes (*Alopex lagopus*) (Quinlan and Lehnhausen 1982). Swennen (1968) seldom observed distraction displays, and only among female eiders with eggs that were pipping or with young already hatched. Here, we report on distraction displays that we observed frequently among Common Eiders nesting on a small island in East Bay, Southampton Island, Northwest Territories, and speculate why it occurs there.

We observed nesting eiders in 1996 on an island in East Bay, southeastern Southampton Island (64°02'N, 81°47'W). The island was approximately 800 m × 100 m and was comprised of extensive boulder fields and gravel beaches. The island supported one of the highest densities of breeding Common Eiders in the eastern Canadian Arctic (Abraham and Ankney 1986).

Approximately 3600 nesting pairs of Common Eiders occurred on the island in 1996. Eiders began nesting about 20 June with the peak of laying around 2 July. Mean clutch size was 3.7 ± 1.1 eggs ($n = 200$). Pair bonds remained until approximately the second week of July with the first molting males observed 11 July. Herring Gulls (*Larus argentatus*) were the main avian predator of eider nest, however, one pair of Parasitic Jaegers (*Stercorarius parasiticus*) visited the colony almost daily in July. Two Arctic Foxes were present on the island until 1 July. We left the colony prior to hatching, but estimated that the peak of hatch would have occurred about 28 July.

While nest-trapping Common Eiders in July 1996, we observed the response of females to human disturbance. Approximately 90% ($n = 201$) of the birds sat motionless on their nests until we approached to within 4–8 m. They typically defecated on their eggs as they left the nest. Similar responses have been observed previously (Swennen 1968; McDougall and Milne 1978; Quinlan and Lehnhausen 1982; Gotmark and Ahlund 1984). At East Bay, however, 15% ($n = 201$) of females that were disturbed feigned a broken wing within 5–20 m from the nest. To our

knowledge, this is the highest incidence of injury-feigning reported for this species. The proportion of females which exhibited displays may also be an underestimate for this colony because distraction displays have been most commonly observed towards the end of incubation or when young are close to leaving the nest (Swennen 1968; Mallory and Weatherhead 1993). Our observations occurred prior to this period, with even early nesters still requiring at least seven days of incubation.

We also observed "false-brooding" behavior (squatting some distance from the nest as if brooding) combined with "nest betrayal" behavior (luring a predator from one's nest by displaying at another nest) in a single female. In this instance the female flushed from the nest and, while simulating a broken wing, proceeded to another nest 3 m away. She sat on the exposed eggs of the neighboring nest while vigorously shaking her wings and fluffing her feathers. She pulled at the nest down with her bill, which further exposed the eggs to us. We banded this female and her neighbors so that we could distinguish them, and on a subsequent visit, she was found sitting on the same neighboring nest. We were later able to observe these birds at a distance with a 20–40× spotting scope and found that all females returned to brood their respective clutches.

Although distraction displays are commonly observed among ground-nesting birds like shorebirds (Simmons 1955; Gochfeld 1984; Brunton 1986; Burger and Gochfeld 1994), and some duck species (Stephen 1963; Armstrong 1965; Jacobsen and Ugelvik 1992; Mallory and Weatherhead 1993; Forbes et al. 1994), there is little evidence that they occur regularly among eiders.

There are at least three possible explanations for this. First, distraction displays could have been previously observed but not reported by earlier researchers. We have no way to assess this possibility, but believe that this is unlikely given the amount of literature on eider reproduction and behavior.

Second, Common Eiders often nest on offshore islands, likely resulting in reduced nest predation by mammals (McDougall and Milne 1978; Quinlan and Lehnhausen 1982; Gerell 1985; Divoky and Suydam 1995; Robertson 1995). Contact with terrestrial predators, therefore, is limited and eiders may have evolved anti-predator strategies specific to avian predators.

A third explanation considers that the risk of predation for the female during distraction displays is high. Eiders are vulnerable to mammalian predators because they have a high wing-loading which makes take-off difficult, and they are awkward on land (Swennen 1968). These factors increase the risk of predation for the female, and presumably decrease the fitness value of distraction displays. This is especially true for eiders, as they are long-lived (Cooch

1986), and may produce many clutches in a lifetime. The fitness value of each clutch, therefore, is low when compared to many other ground-nesting birds (Korschgen 1977).

The high frequency of distraction displays observed at the East Bay colony is surprising because factors which select against this behavior are present at this site (i.e., rough terrain and calm wind conditions make it difficult for eiders to take flight). Common Eiders at this colony, however, may have evolved predator responses specific to this location. Our study site is not a functional island for much of the eider breeding season because it is connected to the mainland by ice during the egg-laying and early incubation periods. Two Arctic Foxes were observed on the island in 1996, and an unoccupied fox den provided evidence of previous fox occupation. Female eiders at this site are thus subject to terrestrial predators, and this may have influenced the frequency with which distraction display behaviors are expressed.

However, it is unlikely that female eiders evolved this trait at this colony. This would require high philopatry of both males and females, and low immigration of individuals that could dilute genetically the expression of the behavior. These conditions do not occur at most Common Eider colonies because pairing takes place on the wintering grounds (Swennen 1990). Consequently, there is low philopatry and high immigration among males at colonies. The fact that these behaviors are observed elsewhere (Williamson 1948; Swennen 1968; Quinlan and Lehnhausen 1982), although rarely, suggests that distraction displays are genetically based among eiders across a broad geographic range.

What appears to be unique at this site is the frequency with which distraction displays occur. Common Eider females are known to return to their former nest sites, (Gerell 1985; Swennen et al. 1993), and successful nest defense strategies may be learned among waterfowl (Forbes et al. 1994). It is possible that female eiders in East Bay express these behaviors because they regularly interact with Arctic Foxes during successive breeding seasons. We predict that older females should be most likely to respond with distraction displays when approached by terrestrial predators.

Although the mechanism for establishing the high frequency of distraction displays at this colony is unknown, these behaviors could reduce egg predation by Arctic Foxes in at least two ways. A fox could be immediately drawn away for the nest to predate the exposed eggs of a neighbor. Second, the number of eggs taken from a single nest could be reduced if eggs were taken from several adjacent nests and the fox became satiated.

Further study is required to (1) quantify the effects of distraction displays on Arctic Fox predation, (2)

quantify the mortality risks associated with these behaviors to female eiders, (3) identify site-specific factors that may influence these behaviors (e.g., topography around the nest), and (4) whether these behaviors also occur at other colonies in the region around Southampton Island.

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Free-ranging Eurasian Beavers, *Castor fiber*, Deposit Anal Gland Secretion when Scent Marking

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Rosell, Frank, and Frode Bergan. 1998. Free-ranging Eurasian Beavers, *Castor fiber*, deposit anal gland secretion when scent marking. *Canadian Field-Naturalist* 112(3): 532–535.

Two adult free-ranging Eurasian Beavers (*Castor fiber*) were observed depositing anal gland secretion at the border of their territory by everting the "cloaca", protruding the anal gland openings and rubbing them against the surface as the animal walked over the scent mound. We suggest that anal gland secretion applied to scent marks on land has some as yet unknown function in territory defense of the Eurasian Beaver.

Key Words: Eurasian Beaver, *Castor fiber*, scent marking, anal gland secretion, Norway.

Scent marking apparently plays an important role in territory defense of both the Eurasian Beaver (*Castor fiber*) (Nolet and Rosell 1994; Rosell and Nolet 1997; Rosell et al. 1998) and the North American Beaver (*C. canadensis*) (Houlihan 1989; Welsh and Müller-Schwarze 1989). Scent is usually secreted onto small piles of mud and debris close to the water's edge (Wilsson 1971; Rosell and Nolet 1997). All age classes and both sexes mark within the territory (Wilsson 1971; Buech 1995). Scent marks are assumed to signal occupancy to potential intruders, notably dispersing subadults (Svendsen 1980; Rosell and Nolet 1997; Rosell et al. 1998), and are deposited in greatest concentrations at territorial borders during the entire year (Rosell et al. 1998).

Both Eurasian and North American beavers possess a pair of anal glands and a pair of castor sacs located in two cavities between the pelvis and the

base of the tail (Walro and Svendsen 1982; Valeur 1988). Both seem to be involved in chemical signaling. The anal gland is a holocrine secretory gland, but the castor sac is only a pocket lined with a layer of nonsecretory epithelium. Both open into the urogenital pouch (cloaca). Anal glands are under seemingly more muscular control than are castor sacs (Svendsen 1978). Beavers deposit copious amounts of castoreum on scent mounds apparently by flushing castoreum out with the urine (Svendsen 1978). Castoreum is deposited on the scent mound without the animal actually making contact between the body and the substrate. In contrast, anal gland papillae must be "rubbed" on the substrate in order to deposit exudate from the anal gland (Wilsson 1971; Svendsen 1978).

It is at present uncertain whether or not anal gland secretion (AGS) is used in scent marking by beavers.

Sun and Müller-Schwarze (1997) report that North American Beavers actively deposit castoreum while marking, but how the AGS is deposited needs to be clarified. Schulte et al. (1994) report that beaver mounds are marked with urine and castoreum from castor sacs, and possibly with AGS. Tang et al. (1995) report that beavers deposit castoreum and AGS, and Tang et al. (1993) report that beavers apply castoreum to scent mounds, but mention nothing about AGS. On the other hand, Wilsson (1971) and Owesen (1979) observed captive Eurasian Beavers depositing AGS when scent marking. Hodgdon (1978) also noted that free-ranging North American beavers deposited AGS on scent mounds. Recently, several authors have studied the response of beavers to artificial scent mounds (Müller-Schwarze and Houlihan 1991; Schulte 1993; Sun 1996), but none observed that resident beavers responded by depositing AGS (L. Sun, personal communication; D. Müller-Schwarze, personal communication). The aim of this study was to monitor Eurasian Beavers depositing AGS at their territory border where marking activity was known to be intense.

On 21 July 1997, we were stationed at the border between two territories with high scent marking activity in the Bø River (59°25'N, 09°03'E), Telemark County, Norway. At this northerly latitude, light conditions during summer allow filming throughout most of the night. The animal living downstream belonged to territory 4 (hereafter animal 4) and the animal upstream to territory 3 (hereafter animal 3). The animals were of unknown sex and estimated age for both was ≥ 2 years. We videotaped the movements of the beavers from the opposite bank (30 m) from 2145 to 2225 hours and later analyzed behavior from the tape.

Both animals were observed depositing AGS at their common border by everting the "cloaca", protruding the anal gland openings and rubbing them against the surface as the animals walked over their scent mounds. When scent marking, the beavers held their tails rigid and almost horizontal just above the ground, afterwards dragging the tail over the scent mound. Once, a beaver sat on the mound during marking, after first having protruded the anal gland. The beavers were never in a hurry to leave the marking site following the deposition of AGS.

Beaver 4 scent marked five times with AGS at four different sites. It was also seen scent-marking on seven other occasions but we were not able to determine if AGS was deposited. Beaver 3 was observed scent marking once with AGS, at the same site marked a few minutes earlier with AGS by the first beaver. On two other occasions, it was impossible to determine if beaver 3 scent marked with AGS. After beaver 3 had over-marked the mound previously marked by its neighbor, the first beaver

promptly returned to mark the same site two more times. Both times it sniffed intensely at the mound before over-marking. Once, after the first over-marking, both beavers tail-slapped while only 15 m apart.

Our observations are apparently the first of free-ranging Eurasian Beavers depositing AGS when scent marking. Hodgdon (1978) never observed North American Beavers sitting on the mound during marking. He reported that animals characteristically galloped or rushed to water and entered as soon as the body was away from the mound, though occasionally they would move away and feed. However, Eurasian Beavers never rapidly departed from the scent marking site (Wilsson 1971; this study). Hodgdon (1978) observed that North American Beavers held the tail rigid, horizontal and elevated above the ground, without dragging over the mound following scent marking as we observed.

Other field observations (Rosell et al., unpublished) indicate that the beaver under certain circumstances use castoreum or AGS, or both. The odor of scent marks, as detected by humans, varies greatly within a site (Rosell et al. unpublished; B. Schulte, personal communication). Whether this is due to different beavers or different scents (castoreum and AGS differ in smell), or a change in the nature of the site over a short-time period, is uncertain (B. Schulte, personal communication). On the basis of both visual and olfactory cues, Bergan (1996) suggested that castoreum was secreted far more frequently than AGS, particularly in winter.

The AGS of the Eurasian and the North American Beaver is sexually dimorphic (Grønneberg and Lie 1984; Sun 1996; Rosell et al. 1997), and the color and viscosity of AGS can be used for sexing both beaver species (Grønneberg and Lie 1984; Owesen 1979; Valeur 1988; Schulte et al. 1995). We assume that in areas where the two species occur together (see Nolet and Rosell 1998), AGS deposited on scent mounds is very important for species recognition.

The North American Beaver has also recently been shown to use the AGS to discriminate between unfamiliar sibling and unfamiliar non-relatives (Sun and Müller-Schwarze 1997), and Schulte (1998) found that North American Beavers discriminated among castor-fluid scents from family, neighbour, and nonneighbour adult males. Therefore, information about kinship is probably contained both in AGS and castoreum. However, field tests including both AGS and castoreum still need to be carried out to determine if the Eurasian Beaver also can discriminate among scents from family, neighbour, and non-neighbour individuals. However, our observations may suggest they do. Both AGS and castoreum from a strange conspecific can elicit territorial responses (Hodgdon 1978; Walro 1980; Welsh and Müller-Schwarze 1989).

One major difference between the two marking organs of beaver may be important for the function of scent marking behavior. Castoreum has a low molecular weight (volatile) and AGS has a higher molecular weight (Grønneberg 1978; Grønneberg and Lie 1984; Tang et al. 1993, 1995; Sun 1996). This may indicate that castoreum informs intruders about territory occupancy at a distance, while AGS works at close range. Indeed, most of the lipids in the AGS are of molecular weight above 300 and will thus normally not be volatile enough to act as "chemical messenger" through the air (Grønneberg and Lie 1984).

AGS seems to have many different functions. Information about kinship is coded in the AGS, and scent from anal glands differ between the sexes and also between the two species. So far, most researchers have given castoreum most attention when studying scent marking behavior. However, our findings indicate that the function of AGS in territory defense should be examined more closely. We suggest that AGS applied to scent marks on land has some as yet unknown function in territory defense of the Eurasian Beaver.

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Pine Marten, *Martes martes*, as a Eurasian Beaver, *Castor fiber*, Lodge Occupant and Possible Predator

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Rosell, Frank, and Bjørnar Hovde. 1998. Pine Marten, *Martes martes*, as a Eurasian Beaver, *Castor fiber*, lodge occupant and possible predator. *Canadian Field-Naturalist* 112(3): 535–536.

We trapped three adult Eurasian Pine Martens (*Martes martes*) at an earlier trapped-out Eurasian Beaver (*Castor fiber*) lodge in southern Norway. At another site, Pine Marten feces containing remains of beaver claws and hair were found outside a beaver lodge. Pine Martens apparently feed on beavers and use their abandoned lodges as resting sites.

Key Words: Eurasian Beaver, *Castor fiber*, Pine Marten, *Martes martes*, lodge, Norway.

Whereas Eurasian Pine Marten (*Martes martes*) and Eurasian Beaver (*Castor fiber*) co-habit the same ecosystems little has been reported on their relationship. This paper documents two independent interactions between these species.

In late December 1991 and early January 1992, we captured two male and one female adult martens at an earlier trapped-out Eurasian Beaver lodge in southern Norway (59°25'N, 09°03'E). At that time of year there had been an abrupt drop in temperature from + 2.8°C to -8.2°C (measured at 0700), and snow depths (3–15 cm) fluctuated greatly. Many Pine Marten footprints around the lodge the day before the first capture indicated that martens used it as a temporary resting site.

High thermal conductance raises the energetic costs of thermoregulation in *Martes* sp. (Iversen 1972; Worthen and Kilgore 1981; Buskirk et al. 1988; Harlow 1994). Both Pine Martens and American Martens (*Martes americana*) reduce energetic costs in winter by seeking insulated underground resting sites (Buskirk 1984; Buskirk et al. 1989; Brainerd et al. 1995). Resting in an abandoned beaver lodge may have provided Pine Martens with protection against cold weather.

In June 1997, we found a 25 cm diameter hole in the roof of another beaver lodge located 3 km from that previously described. The lodge had been occupied the previous winter by a beaver family. The entrances to the lodge were located under water. About 20 cm in front of the hole we found feces of a Pine Marten on a twig. The feces contained remains of beaver claws and hair. On the basis of the size and shape of the remains, the marten had fed on a one-

year-old beaver. No mud or twigs were found scattered outside the hole, which suggest that the beavers had somehow become trapped within its own lodge and had been forced to excavate a hole from within to get out. Fresh tooth marks on the twigs, inside the hole, supported this conclusion. A Pine Marten may have entered through this hole and either killed or scavenged the beaver.

The beaver's aquatic lifestyle and habit of constructing partially submerged lodges under masses of earth and sticks (Wilsson 1971; Zurowski 1992) has seemingly limited the number of its effective predators (Rosell and Parker 1996). Rosell et al. (1996) reviewed the causes of mortality in beaver (*Castor* spp.), but did not mention the Pine Marten as a possible beaver predator. Neither does Martin (1994) identify beavers as marten food items. Whereas in this observation it was not possible to confirm that Pine Martens prey on beaver, it does establish that martens visit beaver lodges and feed on this rodent. On the basis of size alone, we suggest that young beavers may be more susceptible to predation. Young beavers may be captured on land (Kile et al. 1996), or when left unprotected in lodges that are opened by the beaver themselves or by bears (*Ursus* spp.) (Tyurnin 1984; Smith et al. 1994). A drop in water levels can also expose lodge entrances and render young animals more vulnerable to predation.

Acknowledgments

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Zinc Tolerance in Wavy Hairgrass, *Deschampsia flexuosa*, Growing in Acid Soil Beneath a Corroding Galvanized Electrical Transmission Tower

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Bendimir, Axel M., and Roger Jones. 1998. Zinc tolerance in Wavy Hairgrass, *Deschampsia flexuosa*, growing in acid soil beneath a corroding galvanized electrical transmission tower. *Canadian Field-Naturalist* 112(3): 536–538.

A population of Wavy Hairgrass growing in Zn-contaminated, acid soil beneath a corroding galvanized electrical transmission tower on the Precambrian Shield near Kaladar, Ontario, Canada, exhibited tolerance to Zn in a hydroponic root growth experiment. The selection of tolerant individuals of this species and subsequent establishment of the population must have occurred relatively rapidly since the tower was 32 years old when plants were collected for Zn tolerance testing.

Key Words: Wavy Hairgrass, *Deschampsia flexuosa*, zinc, tolerance, galvanized electrical transmission towers, ecotype, Ontario.

The Wavy Hairgrass, *Deschampsia flexuosa* (L.) Trin, is an abundant species of dry, acidic habitats in parts of the Precambrian Shield (Dore and McNeill 1980). Jones and Burgess (1984) reported that in 1980 isolated tufts of this grass were the only plants growing in Zn-contaminated, acid soil (pH = 5.1 ± 0.1, n = 3) in a natural drainage channel leading from a corroding electrical transmission tower constructed on a granitic outcrop of the Precambrian Shield, near Kaladar in southern Ontario, Canada.

They reported concentrations of 1535 ± 129 µg of Zn per g dry weight (n = 4) in *D. flexuosa* shoots from the drainage channel, whereas 13 m upslope from the tower, shoot Zn concentrations were ca. 10 times lower (159 ± 15 µg⁻¹). Tolerance to high soil-Zn has been reported in a number of plant populations (for example, Antonovics et al. 1971; Cox and Hutchinson 1980; Bradshaw and McNeilly 1981; Al-Hiyaly et al. 1990). Based on these reports, it is suggested that, as the concentration of Zn in the soils

beneath the Kaladar tower increased due to corrosion of the protective Zn coating on the tower, selection may have given rise a population of *D. flexuosa* tolerant to Zn. This note reports the results of a hydroponic test for tolerance to Zn by roots of tillers of *D. flexuosa* collected under and around the same Kaladar tower.

Materials and Methods

The transmission tower is located on the south side of the Trans Canada Highway, near Kaladar, Ontario, Canada at 44° 33'N, 77° 15'W. Small tufts (30), of *D. flexuosa*, each consisting of several tillers, were collected randomly under the tower and within 5 m of the tower in small channels which carried run-off from the corroding lattice structure. A further 30 tufts were collected 60 m south-west of the tower, in the up-wind direction of the generally prevailing wind. At such a distance it is unlikely that the soil is being contaminated with Zn from the tower.

Soil was shaken from the roots of the tufts for later analysis and individual tufts were rinsed thoroughly with tap water. The tufts were placed in quarter-strength Hoagland's solution (Hoagland and Arnon 1950) for two months of growth. Then healthy individual tillers were removed from respective tufts for the hydroponic culture root-growth tolerance test described in Al-Hiyaly et al. (1988). Tillers, replicated two to four times, depending on the size of the tufts from which they were collected, were selected to determine root growth in quarter-strength Hoagland's solution (Hoagland and Arnon 1950) containing Zn (as zinc sulphate) selected from the following range of concentrations, 0, 2.5, 5.0 or 7.5 $\mu\text{g Zn l}^{-1}$, giving solutions of pH 6.0, 5.8, 5.6 and 5.5, respectively). The roots of each tiller, clipped to 4-cm length, were inserted into a 5-cm long plastic drinking straw for support. Individual straws were inserted in Styrofoam sheet (6 cm \times 6 cm and 2 cm thick) so that the roots were immersed in 250 ml of the respective test solution contained in an aluminium-wrapped glass jar. Jars, with replicates arranged in a randomised block design, were placed beneath Gro-lux lamps with a photoperiod of 14 h. The ambient temperature during the test was $22 \pm 3^\circ\text{C}$. Solutions were changed every 3 to 4 days and after 4 weeks, the longest root of each tiller was measured and tolerance indices were determined for each Zn concentration using the method of Jowett (1964):

Tolerance index =

Mean length of longest root in the solution with Zn

Mean length of longest root in the solution without Zn

Total Zn in oven-dried (110°C), ground (100 mesh) soil was determined by pre-digesting, at low heat, the soil with 3 ml of concentrated HNO_3 in glass tubes in an aluminium heating block (Allen

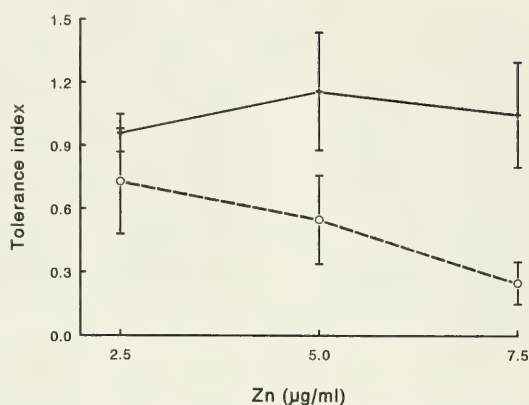


FIGURE 1. Tolerance indices for roots of *Deschampsia flexuosa* collected beneath and 60 m from a corroding galvanized electrical transmission tower. The vertical bar represents the standard deviation for respective mean data points.

1974). Then 3 ml of aqua regia were added and the digestion continued for a further 2 h at increased heat. The cooled digest was brought to 100 ml with N HCl and filtered for Zn determination by atomic absorption spectrophotometry (AAS). Analysis of three replicates of a river sediment sample (NBS Reference Material 1645, United States Department of Commerce) gave concentrations of Zn that were in the certified range of $1720 \pm 169 \mu\text{g g}^{-1}$. Available Zn was determined by extracting 2 g of air-dried soil with two consecutive lots of 20 ml 0.1 N HCl (Baker and Amacher 1982), each time shaking the mixture for 5 min and filtering. The combined filtrate was brought to 50 ml with 0.1 N HCl for analysis by AAS. Soil pH was determined for a 1:1 mixture of fresh soil and de-ionised water with a glass calomel electrode (Jackson 1958). Finely-ground, oven-dried soil was muffled at 550°C for 3 h to determine loss on ignition as a measure of organic content.

Results and Discussion

The soils under the tower and 60 m upwind from the tower had organic contents of 25.3 ± 20.5 (\pm SD) and 20.4 ± 11.4 % dry weight, respectively. The pH of the soils from the two sites was similar, being in the range 5.5 to 6.0. A t-test indicated that there were, however, significant differences ($P \leq 0.05$) between the concentrations of total and extractable Zn, respectively, in soil shaken from roots of samples of the *D. flexuosa* populations collected from the two sites. The total Zn in soil shaken from plants growing 60 m upwind of the tower was $10 \pm 5 \mu\text{g g}^{-1}$ and the extractable Zn was less than $0.05 \mu\text{g g}^{-1}$, whereas the total and extractable Zn in soil shaken from roots of plants growing under and close to the tower were considerably higher at $5851 \pm 7621 \mu\text{g g}^{-1}$

and $95 \pm 82 \mu\text{g g}^{-1}$, respectively. Large differences in concentrations of total and available Zn, respectively, in the soil beneath and immediately around the tower reflects the spatial variability of the amount of soil situated between the protruding bedrock and differences in local drainage patterns.

The hydroponic root-growth test for tolerance to Zn demonstrated that roots of tillers from plants growing upwind of the tower (control, $n = 8$) showed significantly reduced growth (Figure 1) as the concentration of Zn in solution increased from 2.5 to $7.5 \mu\text{gml}^{-1}$ (for $2.5 \mu\text{gml}^{-1}$, $t = 2.44$, $n_{\text{Zn}} = 13$, $P = 0.024$; for $5.0 \mu\text{gml}^{-1}$, $t = 5.82$, $n_{\text{Zn}} = 15$, $P = 0.001$; for $7.5 \mu\text{gml}^{-1}$, $t = 8.69$, $n_{\text{Zn}} = 9$, $P = 0.001$) whereas growth of roots produced by tillers grown from plants collected beneath the tower was unaffected by the range of Zn concentrations used in this test. These data indicate that high available Zn in the acidic soil below the corroding tower has lead to selection for a tolerant ecotype of *D. flexuosa*. Furthermore, the fact that the tower was constructed in 1958, suggests that selection for Zn tolerance by *D. flexuosa* occurred during the following 32-year period and possibly earlier since high Zn concentrations had already been found in shoots of *D. flexuosa* growing beneath the tower (Jones and Burgess 1984).

Even though *D. flexuosa* plants were collected from just one tower, it is likely that other tolerant populations of this species are growing beneath other corroding towers on the Canadian Shield, particularly as this is a widespread species (Dore and McNeill 1980) and *D. flexuosa* is often present beneath or near to towers where general floristic biodiversity is reduced. In Europe, tolerance to manganese (Mahmoud and Grime 1977), lead (Hoiland and Oftedal 1980), and aluminium (Hackett 1965) has been shown in *D. flexuosa*. However, despite the fact that *D. flexuosa* is colonizing formerly barren metal contaminated soils at Sudbury, Ontario) 20 years after smelter closure (Winterhalder 1996), Archambault (1989) concluded that populations growing on metal-contaminated Sudbury soils were not more metal tolerant than control populations.

This study is the first one reporting Zn tolerance due to galvanized transmission towers in Canada. Transmission lines may provide a useful source of Zn-tolerant plants for revegetation of Zn-contaminated sites.

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Triplets in Mountain Goats, *Oreamnos americanus*

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Hoefs, Manfred, and Uli Nowlan. 1998. Triplets in Mountain Goats, *Oreamnos americanus*. Canadian Field-Naturalist 112(3): 539–540.

On 4 June 1997 a set of triplets was born in a captive herd of Mountain Goats (*Oreamnos americanus*). We attributed this rare event to supplemental feed, which also resulted in early sexual maturity, larger body sizes, and a secondary sex ratio distorted toward females.

Key Words: Mountain Goats, *Oreamnos americanus*, productivity, triplets, food quality.

Mountain Goats (*Oreamnos americanus*) typically give birth to single kids, but twinning has been observed, particularly in populations that have been introduced into good quality habitats (Chadwick 1983; Hutchins 1984; Lentfer 1955; Wigal and Coggins 1982). Only one documentation of triplets, in the Crazy Mountains of Montana, has been reported (Lentfer 1955). However, this report leaves room for doubt, and we agree with Chadwick's (1983) assessment of it, when he writes:

"In the early 1950's Jack Lentfer conducted an important study of goats transplanted into Montana's Crazy Mountains. He not only found twinning to be quite common but reported several instances of triplets, an unheard-of occurrence in *Oreamnos* before or since. Those Crazy Mountain Goats were plainly flourishing in this nonnative range. Yet since I have seen two to as many as five kids playing together and tagging along

behind a single nanny for up to half an hour before returning to their own mother nearby, and since many of Lentfer's observations were necessarily brief parts of overall population censuses, I've never been absolutely convinced about these triplets."

On 4 June 1997 a set of triplets was born at the Yukon Game Farm near Whitehorse, Yukon. They were born in a captive herd, with each goat individually marked and under daily observation (Figure 1). The mother was seven years old and weighed 73.6 kg on 1 November 1997. The sex ratio of the triplets was 2 males : 1 female. The captive herd, established for display and research purposes, originated in 1976 with the capture of eight goats in Yukon's Coast Mountains. The enclosure is 5.9 ha in size and resembles typical Yukon Mountain Goat winter range in terms of terrain type and vegetation cover. Since its



FIGURE 1. Nanny Mountain Goat with her 11-week old triplets photographed 18 August 1997. Note the delay in pelage change characteristic for lactating females.

establishment, this herd varied in size from 8 to 30 goats, depending on kid production and disposition of goats to other institutions. The herd obtains high quality supplementary feed with alfalfa hay (14% protein) provided ad lib, plus a specially prepared pellet ration at a rate of 500 g per 45.5 kg of body weight (Hoefs and Nowlan 1994).

Our documentation supports the view that multiple births are a reflection of range quality or nutrition (Hutchins 1984; Rideau and Hoffman 1975). Since its establishment in 1976, 142 kids have been produced in this captive herd: 75 were singles, 64 were twins, and 3 were triplets. Superior nutrition also influenced breeding age, body size and secondary sex ratios (Hoefs and Nowlan 1994). About 50% of the nannies bred as yearlings and gave birth to their first offspring when 2 years old. Adult females had weights of 72.7 to 81.8 kg, with one mature billy reaching 131.8 kg. The sex ratio at birth was distorted toward females with 87 males to 100 females.

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News and Comment

Notices

By-law amendment, Ottawa Field-Naturalists' Club

In accordance with Article 18 of the Constitution of the Ottawa Field-Naturalists' Club, a fee increase necessitates a change in By-laws. Therefore Article 5 of the By-laws has been amended by the Ottawa Field-Naturalists' Council at its 8 June 1998 meeting as follows:

5. Schedule of Dues and Fees		
The current schedule is:		
Memberships	Individual	\$28
	Family	\$30
	Sustaining	\$50
	Life	\$500
Subscriptions		
<i>The Canadian Field-Naturalist</i>		
	Individual	\$28
	Libraries and	
	Institutions	\$45
<i>Trail & Landscape</i>		
	Libraries and	
	Institutions	\$28

DAVID SMYTHE

Call for Nominations: Ottawa Field-Naturalists' Club 1998 Awards

Nominations are requested from members of The Ottawa Field-Naturalists' Club for the following: Honorary Membership, Member of the Year, George McGee Service Award Citation, Conservation, and the Anne Hanes Natural History Award. Descriptions of these awards appeared in *The Canadian Field-Naturalist* 96(3): 367 (1982). The Service Award was renamed the George McGee Service Award in 1993 [see *The Canadian Field-Naturalist* 108(2): 243-244 (1994)]. With the exception of nominations for Honorary Member, all nominees must be members in good standing.

STEPHEN DARBYSHIRE
Chair, Awards Committee

Call for Nominations: The Ottawa Field-Naturalists' Club 1999 Council

Candidates for Council may be nominated by any member of The Ottawa Field-Naturalists' Club. Nominations require the signature of the nominator and a statement of willingness to serve in the position for which nominated by the nominee. Some relevant background information on the nominee should also be provided.

FRANK POPE
Chair, Nominating Committee

Errata: *The Canadian Field-Naturalist* 112(2)

Etcheberry, Roger. 1998. Additions a la flore de Sainte-Pierre et Miquelon. *Canadian Field-Naturalist* 112(4): 337-339

Page 337, left column, line 9, add O after 56°19'50".

Page 337, left column, line 12, replace 600 with 500.

Page 337, right column, line 7, replace l'ouest with l'est.

Page 338, right column, line 6, replace aboard with abords.

Status Evaluation of Animals Inhabiting Canada's Forests

National Status Evaluation of 20 Selected Animal Species Inhabiting Canada's Forests. Final Report by Rob Alvo for The Canadian Pulp and Paper Association, The Biodiversity Convention Office, and The Canadian Forest Service. 8 June 1998. 328 pages.

Discussed are the global distribution, conservation status [based on IUCN, The Nature Conservancy, and Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and, if applicable, the U.S. Endangered Species Act], population size, and a prognosis of the population size of 18 mammals, one amphibian and one reptile.

Available from Canadian Pulp and Paper Association, 155 rue Metcalfe, Montreal, Quebec H3B 4T6, Canada, attention Robert Decarie.

Canadian Species at Risk: April 1998

The Committee on the Status of Endangered Wildlife in Canada has released a booklet *Canadian Species at Risk: 1998* (iv + 121 pages) listing the 307 species in Canada that have been classified at Extinct, Extirpated, Endangered, Threatened, or Vulnerable. An additional 121 species have been evaluated and found to be not at risk, and 19 species have been designated indeterminate. The latter are species for which there is insufficient scientific information to allow a status designation. This booklet is available from the COSEWIC Secretariat c/o Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3; e-mail sylvia.normand@ec.gc.ca; shirley.sheppard@ec.gc.ca; Web site <http://www.cosewic.gc.ca>.

Recovery: An Endangered Species Newsletter

The spring 1998 issue, coordinated by the Canadian Wildlife Service and edited and designed by West Hawk Associates, features Recovery of tallgrass species underway (Lindsay Roger); Celebrating a 10-year anniversary (David Wylynko); Improving the national species recovery process (Simon Nadeau); New homes for imperiled trout (John Gunn); 18 Species added to national list (COSEWIC, spring 1998 meetings); Twenty years of COSEWIC: an overview (Christopher C. Shank); Committee contributors recognised (93 individuals who aided COSEWIC); Wired for wildlife (James Hrynshyn); A tale of two snakes: conservation of the black rat snake and the massasauga (Kent A. Prior); The History of the Golden Seal (Paul Catling and Adrienne Sinclair).

Recovery is available from the Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3, Canada or is accessible on the net at www.ec.gc.ca/cws-scf/es/recovery/eng/index.html

Recovery of Nationally Endangered Wildlife: RENEW Report Number 8 1996/97

This 52-page booklet marks the Tenth Anniversary of the Committee on the REcovery of Nationally Endangered Wildlife. Research, editing and production coordination are by West Hawk Communications. Research and coordination are by Lisa Twolan and Simon Nadeau of the Canadian Wildlife Service. It includes species recovery updates for 35 taxa (species or subspecies) or discrete populations and one ecosystem, as well as comprehensive lists of recovery teams and Canadian species at risk. It is available from Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3.

Global Biodiversity: Canadian Museum of Nature

Volume 8, Number 1, Summer 1998 contains two features: Mapping a Great Big Sea (I. D. Cresswell and R. Thackway, Environment Australia); Exploring Biodiversity to the Ends of the Earth (Mark Graham, Canadian Museum of Nature); an Editor's Notebook (Globalization and biodiversity) and 8 departments: Forum (Funding for conservation biologists, MAI), Portrait of Biodiversity (*Nicropus sayi*), Successes and Initiatives (Malaysia, CIBE, Biodome), Meetings, News, Book Reviews. The Last Word (The Rideau River - An Ecosystem to Discover: Michel Poulin).

Global Biodiversity is edited by Don E. McAllister, and the Managing Editor is Dory Cameron. It is published by the Canadian Museum of Nature, P. O. Box 3443, Postal Station D, Ottawa, Ontario K1P 6P4, Canada. For Subscription Sales contact Louisa Guglielmo, telephone: (613) 566-4784 or 1-888-437-6287; Fax: (613) 566-4763; e-mail: biodiv@mus-nature.ca.

For further information, access URL: <http://www.nature.ca>

Sea Wind: Bulletin of Ocean Voice International

Volume 12, Number 1, 48 pages, January-March 1998, includes articles on: Conservation of cold- and warm-water seafans: threatened ancient gorgonian groves; Canadian northern corals need immediate protection!!; Mixing mussels: is introduction a threat to the native Pacific coast blue mussel?; and Lobster conservation work in Newfoundland. Volume 12, Number 2, 40 pages, April-June 1998, includes articles on Cyanide fisheries: where do they start?; CIDA grant received to develop a Greater Caribbean coral reef care manual; Ornamental fish international grant for aquarium fish project; New manager for PMP ornamental fish export facility; Universal declaration of human rights; Flashback to 1986 - origins of Palawan's live reef food fish trades: raising the stakes in the cyanide controversy; Oil slicks, a threat to eggs, embryos and larvae of marine fishes and to fisheries?; Fishers survival - from kings and corporations.

Sea Wind is available through membership in Ocean Voice International P. O. Box 37026, 3332 McCarthy Road, Ottawa, Ontario K1V 0W0, Canada; e-mail: mcall@superaje.com; World-Wide Web site: <<http://www.ovi.ca>>.

Froglog: Newsletter of the Declining Amphibian Populations Task Force (DAPTF)

Number 27, June 1998, contains: Effects of the El Nino Drought on the Frogs of Papua New Guinea by David P. Bickford; *Bufo marinus* Decline and Recovery in Trinidad by Victor C. Quesnel; Pennsylvania Herpetological Atlas Project by Mary S. Kostalos; Froglog Shorts, and Publications of Interest.

Number 28, August 1998 contains: The Effects of Habitat Modification on Spotted Frogs in Yellowstone National Park by Debra A. Patia; Midwest Declining Amphibians Conference a Hopping Success from Gary Casper, DAPTF USA-Great Lakes; Amphibians in Arunachal Pradesh, India by Sabitry Choudhury Bordoloi; Declining Amphibian Populations: Looking for Large Scale Patterns by Jeff Houlahan; Grant Opportunities; DAPTF-Netherlands Report from Gerard Smit; NSF Workshop on Declining Amphibian Populations; Froglog Shorts; Publications of Interest.

Froglog is available from Editor John W. Wilkinson, Department of Biology, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk and on the World Wide Web at the following URL: <http://acs-info.open.ac.uk/info/newsletters/FROGLOG.html>

Marine Turtle Newsletter

This quarterly publication deals with marine turtles in the world. Numbers 80 (April 1998) and 81 (July 1998), each 20 pages, edited by Brendan J. Godley and Annette C. Broderick, Marine Turtle Research Group, Division of Environmental and Evolutionary Biology, Graham Kerr Building, University of Glasgow, Glasgow G12 8QQ Scotland, United Kingdom; e-mail MTN@bio.gla.ac.uk; Fax +44 141 330 5971.

Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; Fax + 1 978 840 8184. MTN website is: <<http://www.seaturtle.org/mtn/>>

Canadian Association of Herpetologists Bulletin

Volume 12, Number 1, spring 1998 contains includes "news" updates on Richard Wassersug's group at Dalhousie University, Halifax, Nova Scotia, and Tony Russell's group at the University of Calgary, Alberta. Meeting notices include the ASIH/SSAR/HL/AES/CAH in Guelph in July 1998; the Amphibians and Reptiles of Tropical Forests: Biodiversity and Conservation Meeting in 1999 in Vietnam, and a report on the 1997 ASIH/HL/SSAR meetings in Seattle. Articles are: Nitrate: a tadpoles bane (Jeremy D. Rouse); The effect of timing of cattle grazing on amphibian abundance in central Alberta ponds (Norine E. Ambrose and Cynthia A. Paszkowski; and Clayoquot Sound amphibian inventory (Elke Wind and Barbara Beasley). In Miscellany are: New additions to Canada's endangered species list (David Green and Ron Brooks) and The unique nesting behaviour of northern Spotted Turtles (Jacqueline D. Litzgus). New publications are noted by Jon Davidson and Mike Oldham and Joe Slowinski discusses *Contemporary Herpetology*, a new electronic journal. Thesis abstracts reprinted are: The effects of insularity on the population genetic structure of *Plethodon cinereus* and *Rana clamitans* in Georgian Bay (David Geoffrey Britton, M.Sc. 1998. University of Guelph; Supervisor J. P. Bogart); Breeding site suitability and optimal eggs size in the Spotted Salamander, *Ambystoma maculatum* (David C. Cunningham, M.Sc. 1998. University of Guelph; Supervisor R. J. Brooks); Sexual size dimorphism

and demography, thermoregulation and mating activity of Northern Water Snakes, *Nerodia sipedon* (Gregory P. Brown, Ph.D. 1997. Carleton University, Ottawa; Supervisor P. Weatherhead); Effects of VISION (R) (Glyphosate) on progeny of Wood Frogs exposed in conifer plantations (Janine Damaris Glaser. M.Sc. 1998. University of Guelph; Supervisor J. P. Bogart); Reproductive success, mating strategies and long-term population trends in the Bullfrog, *Rana catesbeiana* (Anura: Ranidae) (Cam MacDonald. M.Sc. 1997. University of Guelph; Supervisor R. J. Brooks); Ecological constraints on growth of Painted Turtles (*Chrysemys picta*) in northern climates (Nicola Koper. M.Sc. University of Guelph; Supervisor R. J. Brooks); The effect of human disturbance on Eastern Massasauga Rattlesnakes (*Sistrurus catenatus catenatus*) in Killbear Provincial Park, Ontario (Christopher Edward Parent. M.Sc. 1997. Carleton University, Ottawa; Supervisor P. Weatherhead).

Membership in the Canadian Association of Herpetologists / Association Canadienne des Herpetologistes is \$10.00 for regular members and \$5.00 for students, payable to Dr. Patrick T. Gregory, Treasurer CAH/ACH, Department of Biology, University of Victoria, Victoria, British Columbia V8W 2Y2, Canada.

The Canadian Amphibian and Reptile Conservation Network

The 3rd annual meeting of The Canadian Amphibian and Reptile Conservation Network and the 8th Annual Meeting of the Task Force on Declining Amphibian Populations in Canada was held in Saskatoon, Saskatchewan 2-4 October 1998. The Program and Abstracts features 26 presentation abstracts. The next meetings will be held in Quebec City, 8-11 October 1999. Contact Stan A. Orchard, Chairman of CARCN, Natural History Section of the Royal British Columbia Museum, 1745 Bank Street, Victoria, British Columbia V8R 4V6; e-mail <sorchard@island.com>

Catalogue of Type Specimens in the Vascular Plant Herbarium of Agriculture and Agri-Food Canada in Ottawa

Installed on the internet at <http://agres:1080/brd/dao/intro.html> 30 October 1996, the *Catalogue of Type Specimens in the Vascular Plant Herbarium (DAO)* is by William J. Cody of the Biological Resources Program, Eastern Cereal and Oilseed Research Centre, Research Branch, Agriculture and Agri-Food Canada, Wm. Saunders Building (49), Central Experimental Farm, Ottawa, Ontario K1A 0C6, Canada [formerly Centre for Land and Biological Resources Research or Biosystematics Research Centre]. The vascular plant herbarium at DAO [Department of Agriculture, Ottawa] was established in 1886 when James Fletcher donated his personal collection. It now totals over 1 000 000 specimens. The list presented here contains references to over 3600 type specimens contained in this collection including holotypes, isotypes, lectotypes, neotypes, paratypes, syntypes, topotypes of species, subspecies, varietal or forma ranks and describer, reference to original description, county, region, location, collector, collection number, collection date and kind of type are all given. Where the last category is uncertain the entry is preceded by "?". Most of the holotypes are for taxa described by former staff members Bernard Boivin, W. M. Bowden, James M. Calder, William G. Dore, John M. Gillett, and Gerald A. Mulligan. Most of the isotypes, paratypes, and topotypes in the list have been donated or received on exchange.

FRANCIS R. COOK

The Ottawa Field-Naturalists' Club 1997 Awards

The 1997 awards were presented at the annual Soirée held at the Unitarian Church in Ottawa on 24 April 1998. The awards are given to recognize and encourage contributions towards the goals of the club by individuals or organizations.

The Macoun Field Club is a club for young Ottawa area naturalists co-sponsored by The Ottawa Field-Naturalists' Club and The Canadian Museum of Nature since 1948. The presidents Sara Potvin-Bernal (Juniors and Intermediates) and Katherine Kitching (Seniors) each spoke on the activities of their respective groups over the last year. Various members provided natural history exhibits and judges Betty Campbell and Trudy Bedford awarded First to Sara and Julian Potvin-Bernal for their display on the Eastern Black Swallowtail Butterfly, Second to Mark Oudin for his display on sharks and Third to Morgan Rowe for her display on the Eastern Gray Squirrel.

OFNC president David Moore presided while Isabelle Nicol and Stephen Darbyshire read the citations for the 1997 awards.

Honourary Member – John A. Livingston

John Livingston is a man among the "Who's Who" of Canadian naturalists and environmentalists. He is responsible for much impetus to the naturalist movement in Canada. A lifelong naturalist and nature advocate, he has pursued his interests on six continents.

Born in Hamilton, Ontario, he graduated with his BA from the University of Toronto. After serving in the RCNVR in the Second World War, he settled into his lifelong work — naturalist and environmentalist.

John Livingston is an accomplished man. While executive producer of the CBC's Natural History Unit, he led film expeditions all over the world and wrote dozens of scripts for television including many *The Nature of Things* programs. He is past president of the Federation of Ontario Naturalists. He served as executive director of the Audubon Society of Canada (now the Canadian Nature Federation) and has been editor of *Canadian Audubon* magazine (now *Nature Canada*). He was a founding trustee of the Nature Conservancy of Canada. And he was a member of the Commission on Education of the International Union for the conservation of Nature.

He is currently professor emeritus in the Environmental Studies graduate program at York University where he was professor from 1972 to 1992.

He is a perceptive writer with an eloquent and forceful style. He is author of *Birds of the Northern Forest* (1966) and *Birds of the Eastern Forest* (1968–70) which feature the paintings of J. F. Landsdowne, *Arctic Oil: The Destruction of the North* (1981), *One Cosmic Instant: A Natural History of Human Arrogance* (1973), *The Fallacy of Wildlife Conservation* (1981), and *Canada: A Natural History* (1988). He is able to render in evocative language relatively complicated philosophies — which culminated in a Governor General's award for his book *Rogue Primate: an exploration of human domestication* in 1994.

The Club is pleased to acknowledge John Livingston's tremendous contributions towards our appreciation of nature and the way in which humans view and interact with the natural world around them.

Anne Hanes Natural History Award 1997 — Allan and Joyce Reddoch

This award goes to Joyce and Allan Reddoch for their monograph "The Orchids in the Ottawa District: Floristics, Phytogeography, Population Studies and Historical Review," published in the January-March 1997 issue of *The Canadian Field-Naturalist* 111(1). It is a comprehensive, 185 page, study of the 44 species of orchids reported in the Ottawa District (area within 50 km of the Peace Tower on both sides of the Ottawa River) since 1856. It includes information on identification, past and present status, blooming periods, colony sizes, habitats and the discovery of sites of the more unusual species. They give credit to government botanists and Club members who helped in the collection of data over many years, particularly through the Native Orchid Location Survey, of which Joyce and Allan became Coordinators in 1977.

This publication has been a true labour of love by these two authors who managed not only to collect information themselves, but also to collate, sort, and where necessary verify all the information that had accumulated over the past 140 years. Their observations are supplemented with drawings and photographs (from which line drawings for the article were prepared by Susan Laurie-Bourke). Many articles were contributed to *Trail & Landscape* prior to attempting this in-depth publication. This is not only an orchid study for academic purposes, but also serves to help plan for their protection, as they are extremely intolerant of disturbance. Both Allan and Joyce have a great concern for conservation of all life and Allan is a past chairman of the Club's Conservation Committee.

It is appropriate for this award to go to Joyce and Allan, not only for a major contribution to the Club's activities over its long history, but also for their great friendship with Anne Hanes over many years. Anne was a member of the Survey team and was very interested in orchids, both from botanical and artistic points of view.

George McGee Service Award 1997 — Bernie Ladouceur

The George McGee Service Award is presented to a person deemed to have contributed significantly to the smooth running of the club over several years.

For the year 1997 the award is presented to Bernie Ladouceur for his many years of work with the Birds Committee, the Christmas Bird Count and related activities. Bernie has served with the Birds Committee for more than 20 years, taking on stints as Chair and Treasurer. He is a member of the Birds Studies Group and the Bird Records Sub-Committee. He has been a sector leader and active participant in the Christmas Bird Count for many years. In 1981 Bernie was the coordinator of the Club's only owl census. Bernie has been working away for many years organizing, recording and reporting on The Ottawa Field-Naturalists' Club birding activities.

Bernie has served as a Council member and contributed dozens of articles on birds to *Trail & Landscape*. He is well known to many members as a hike and excursion leader. He has co-led trips to Presqu'Île and Derby Hill, helping us see and identify hawks in their spectacular migrations. He has left behind a warm and cosy bed on many a winter night to lead groups on owling expeditions.

Bernie was heavily involved with school groups last May in a "Birding Challenge Contest", helping school children to develop their interest in bird watching. He judged each and every journal that was sent in, made written comments on each, then met with the individual students at an assembly where he presented their prizes. An active and well known Birder himself, Bernie is one of only four people who have tallied 203 species last May.

So, it is with great pleasure that The Ottawa Field-Naturalists' Club presents the 1997 George McGee Service Award to Bernie Ladouceur.

Member of the Year 1997 — Eileen Evans

The Member of the Year Award is given to a member deemed to have contributed in a significant way to The Ottawa Field-Naturalists' Club in the past year.

This year we would like to honour Eileen Evans with the Member of the Year Award. In 1997 Eileen has served the club in many ways. She shared her natural history knowledge by contributing articles to *Trail & Landscape* and leading local walks. The food, coffee and tea which are enjoyed at the monthly meetings require time and effort to organize and, in 1997, Eileen continued to be the person taking on this task. She serves us, quite literally, behind the scenes and up front, purchasing all the supplies and organizing the equipment. Setting up and taking down the refreshment table means that she is usually the first person to arrive and the last person to leave the monthly meetings. Eileen, as in past years, also took a major role in organizing the annual picnic.

The committee structure in the The Ottawa Field-Naturalists' Club is the mechanism which insures that things continue to get done and activities run smoothly. In 1997 Eileen served on two hard-working and key committees, the Excursions and Lectures and the Membership committees. In past years Eileen has also served on Council. Without the dedication of committee members in organizing a multitude of tedious little jobs the club activities would not be as rich, enjoyable or smooth-running as they are. It has been said of Eileen that she is always there when you need a hand organizing a club activity.

This evening you will see one more aspect of Eileen's generosity. As in past years, she has once more coordinated the "wine and cheese" for the evening. Not only has she coordinated all the necessary work for this aspect of the soiree, she also plays a major role in the purchase, set up and creation of the food items on the tables. As is characteristic of Eileen, she will be one of the last to leave tonight after helping to clean up what she has worked so hard on to organize. Her hard work, cheerful energy and friendly greetings has made the soiree, monthly meetings and other club activities special events for all of us.

Conservation Award, Member 1997 — Michael Runtz

The annual Ottawa Field-Naturalists' Club Conservation Award is given to a club member in recognition of a recent outstanding contribution to the cause of conservation.

For many years, Mike has worked diligently for the protection of sensitive areas within Algonquin Park and other wild places, especially the Stewartville Bog and Gillies' Grove, a 150-year-old white pine forest owned by the Oblate Fathers who may develop the property. This 60-acre site in Arnprior is the only remnant white pine stand on the south shore of the Ottawa River. Mike is also a strong supporter of the Fletcher Wildlife Garden, which was established, in part, to demonstrate how property owners can contribute to conserving biodiversity in an urban setting - and have a lot of fun doing it.

Mike is one of the most popular lecturers at Carleton University and has authored several books, including *The Explorer's Guide to Algonquin Park*, *Wild Wings: The Hidden World of Birds* and *Beauty and the Beasts: The Hidden World of Wildflowers*. In his words and photos, Mike eloquently conveys his passion for wild things and wild places and engenders in his readers a desire to protect our wild heritage.

Conservation Award, Non-Member — Natural Heritage Information Centre

The Natural Heritage Information Centre was started in 1993 as a joint project between the Ontario Ministry of Natural Resources, Natural Heritage League, The Nature Conservancy (U.S.) and the Nature Conservancy of Canada. After the first two years it became entirely funded by the OMNR. There are presently four biologists on staff as well as a Coordinator, Systems Administrator and GIS/Mapping Specialist. The NHIC maintains databases and tracks rare and endangered species (about 2000 tracked at the present time) as well as endangered habitats throughout Ontario providing information to provincial and municipal governments to assist in planning and land management. The NHIC works closely with other organizations, including The Nature Conservancy, The World Wildlife Fund, the Federation of Ontario Naturalists, the Committee on the Status of Endangered Wildlife in Canada and the Canadian Declining Amphibian Populations Task Force, as well as with Ontario Parks in identifying new possible parks and protected areas.

Apart from their general databasing and monitoring function the NHIC is also involved with several recovery projects for species at great risk, such as Prothonotary Warbler, Acadian Flycatcher, Blanchard's Cricketfrog, Spiny Softshell Turtle, etc.

The NHIC acts as a clearing house for conservation data in Ontario. As well as electronic databases, it maintains a large collection of literature and unpublished reports on parks and areas of biological interest. Much has been accomplished in publicizing its activities and findings through the publication of a newsletter and the development of a WWW site. The social value of the information on Ontario's natural heritage would be limited were it not for the generosity and efforts of the NHIC's staff to make these data widely available for clients to the ultimate benefit of our natural environment.

The NHIC and its excellent staff are to be congratulated on their remarkable achievements in collecting and distributing a wealth of high quality information that will have an unprecedented impact on natural history conservation throughout Ontario.

STEPHEN J. DARBYSHIRE
Chair, and members of the
Awards Committee

Minutes of the 119th Annual Business Meeting of The Ottawa Field-Naturalists' Club, 27 January 1998

Place and Time: Canadian Museum of Nature,
Metcalfe and McLeod Streets, Ottawa, 7:30 p.m.
Chairperson: Dave Moore, President
Attendance: Thirty-one persons attended the meeting.

Dave Moore opened the meeting, noting that it had been rescheduled from the original date of January 13th due to inclement weather and the closing of the Museum on that date. He asked the meeting to spend the first half hour reviewing the minutes of the previous meeting, the Treasurer's Report, and the reports of Committees. The meeting was called to order at 8:00 pm.

1. Minutes of the Previous Meeting

In section 6, Report of the Nominating Committee, in the list of Other Council Members, "Isabel Nicol" should read "Isabelle Nicol". In the following paragraph, "Colin Gaskill" should read "Colin Gaskell". It was moved by Colin Gaskell, (2nd Tom Reeve) that the minutes as amended, be accepted.

(Motion Carried)

2. Business Arising from the Minutes

There was no business arising from the minutes.

3. Communications Relating to the Annual Business Meeting

There were no communications relating to the Annual Business Meeting.

4. Treasurer's Report

Simon Shaw introduced the financial statements for the year ending September 30th, 1997, by noting that due to unforeseen circumstances, a report from the Auditor was not yet available. He reviewed some of the highlights of the statements, including the addition of a statement of "Changes in Net Assets", which permits a quick overview of changes, and a note giving details of the Club's investments. He also noted a decrease in the total equity resulting from losses in both the operations of the OFNC and the publication of *The Canadian Field-Naturalist*, the latter primarily from anticipated losses in revenue in the publication of a special issue. There were several questions from the floor concerning the GST rebate, the Club Reserve and the OFNC Affiliation Fees.

It was moved by Simon Shaw (2nd Frank Pope) that the Financial Statements be accepted subject to a favourable report from the Auditor.

(Motion Carried)

5. Committee Reports

Dave Moore introduced each of the Committee reports and asked for comments and questions. Chris Traynor noted that in the Birds Committee Report, the process of updating the Blue checklist is not yet complete. In answer to a question from Stan Rosenbaum, Cheryl McJannet explained that even though the Club had its own web site on the internet, there was still some value to the Club being on the National Capital FreeNet. The following motions were proposed:

It was moved by Stephen Darbyshire (2nd Elaine Dickson) that the report of the Awards Committee be accepted.

(Motion Carried)

It was moved by Chris Traynor (2nd Fenja Brodo) that the report of the Birds Committee be accepted.

(Motion Carried)

It was moved by Tom Reeve (2nd Isabelle Nicol) that the report of the Computer Management Committee be accepted.

(Motion Carried)

It was moved by Stan Rosenbaum (2nd Fenja Brodo) that the report of the Conservation Committee be accepted.

(Motion Carried)

It was moved by Cheryl McJannet (2nd Lee Cairnie) that the report of the Education & Publicity Committee be accepted.

(Motion Carried)

It was moved by Philip Martin (2nd by Tom Reeve) that the report of the Excursions & Lectures Committee be accepted.

(Motion Carried)

It was moved by Bill Cody (2nd Simon Shaw) that the report of the Finance Committee be accepted.

(Motion Carried)

It was moved by Philip Martin (2nd Betty Campbell) that the report of the Fletcher Wildlife Garden be accepted.

(Motion Carried)

It was moved by Rob Lee (2nd Stephen Darbyshire) that the report of the Macoun Field Club be accepted.

(Motion Carried)

It was moved by Dave Smythe (2nd Chris Traynor) that the report of the Membership Committee be accepted.

(Motion Carried)

It was moved by Bill Cody (2nd Philip Martin) that the report of the Publications Committee be accepted.

(Motion Carried)

6. Nomination of the Auditor

It was moved by Frank Pope (2nd Simon Shaw) that Janet Gehr continue as Auditor for another year.

(Motion Carried)

7. Report of the Nominating Committee

Frank Pope reported that there were no nominations forthcoming from notices placed in *The Canadian Field-Naturalist* and *Trail & Landscape*. There has been such little demand for the services of a Corresponding Secretary in the past few years that the Committee recommended that the position be left vacant this year. The Committee presented the following list of candidates for the 1998 Council (new members are indicated by an asterisk):

President	David Moore
Vice-President	David Smythe
Vice-President	Eleanor Zurbrigg
Recording Secretary	Garry McNulty*
Corresponding Secretary	(vacant)
Treasurer	Simon Shaw
Ronald Bedford	Fenja Brodo
Michael Brandreth*	William Cody
Stephen Bridgett	Francis Cook

Ellaine Dickson
Barbara Gaertner
Alan German
Anthony Halliday*
Jeffrey Harrison
Philip Martin

Cheryl McJannet*
Isabelle Nicol
Frank Pope
Stanley Rosenbaum
Chris Traynor
Dorothy Whyte*

Five members of the 1997 Council decided not to stand for re-election: Lee Cairnie, Michael Murphy, Pat Narraway, Tom Reeve, and Ken Young. Frank thanked them for their contribution to the 1997 Council.

It was moved by Frank Pope (2nd Lee Cairnie) that the proposed slate be accepted.

(Motion Carried)

8. New Business

There was no new business.

9. Presentation by the Macoun Field Club

Rob Lee gave a slide presentation of the history of the Macoun Field Club. Pictures of past field trips and former members, many of whom have gone on to a career in the biological sciences, evoked fond memories for members of the audience. This year is the 50th anniversary of the Club and Rob said that a celebration of that event will take place some time in June.

10. Adjournment

Dave Moore adjourned the meeting at 9:10 pm and invited members to have some coffee.

DAVE SMYTHE
Recording Secretary

Committee Reports for 1997 to The Ottawa Field-Naturalists' Club

Awards Committee

The following awards were presented at the Annual Soiree, held on 25 April 1997:

1996 – MEMBER OF THE YEAR AWARD: Catherine O'Keefe for her active participation in many club activities. Catherine is one of those people who are present at many general activities and who help with the tedious "behind-the-scene" jobs so vital to the smooth running of a volunteer-based organization.

1996 – ANNE HANES NATURAL HISTORY AWARD: Dr. Jack M. Gillett for his many years of work on the vascular plants of the Ottawa District.

1996 – CONSERVATION AWARD FOR MEMBER: Christine Hanrahan and Sandra Garland of the Fletcher Wildlife Garden team for their enthusiasm and drive in this urban wildlife garden project.

1996 – CONSERVATION AWARD FOR NON-MEMBER: Dr. J. Gordon Nelson for 35 years of advocacy and research on parks and conservation areas.

1996 – GEORGE MCGEE SERVICE AWARD: Monty Brigham for his years of leading Club outings and workshops on bird identification.

1996 – HONORARY MEMBER: Bruce Di Labio for many years of sharing his bird observation skills with the Club membership through countless field trips and articles in *Trail & Landscape*. Dr. William O. Pruitt, Jr. for his long-term and greatly appreciated contribution as an associate editor of *The Canadian Field-Naturalist*.

STEPHEN DARBYSHIRE

Birds Committee

The Committee continued its regular activities: the Fall Bird Count, the Ottawa-Hull Christmas Bird Count, the Dunrobin Christmas Bird Count, maintaining the Bird Status Line and the Rare Bird Alert, maintaining the Club bird feeders, and raising money for feeder supplies in the annual Seedathon (\$975 in 1997). The Committee also provided leaders for the

Excursions & Lectures Committee and articles for *Trail & Landscape*.

The Committee organized the May Birding Challenge, a birding journal competition for school-age children to create and promote interest in birding in the youth community, and to foster field skills. It attracted 42 entries. All participants received a letter and a small token, and three pairs of binoculars and three field guides were awarded to the winners.

A Bird Study Group was formed to develop advanced bird identification skills in the birding community. Members of the Committee collaborated with the Ontario Ministry of Natural Resources to monitor a Peregrine Falcon chick that had hatched on the roof of a building in downtown Ottawa. It is planned that the Bird Study Group be used as a training ground for future events of this type.

Members of the Committee helped to organize and run the Fletcher Wildlife Garden's Taverner Cup competition. The Committee sent a certificate of appreciation to Gilbert Dupuis of Chelsea Quebec, for his hospitality to birders when a Boreal Owl visited his property. The Bird Records Subcommittee continued to review the list of rare bird reports. The blue checklist of birds of the Ottawa-Hull region was updated.

CHRIS TRAYNOR

Computer Management Committee

This Year has seen some consolidation of the Club's computer hardware. A new machine purchased last year, has been installed for use in the production of *Trail & Landscape*. T & L's original machine was reconfigured for use by the Editor of *The Canadian Field-Naturalist*, with a modem being installed to allow the Editor to correspond with authors across Canada by electronic mail. Two of the Club's old machines were disposed of at a sale organized by the Fletcher Wildlife Garden Committee, with the proceeds going to support the Garden. New accounting software was purchased for use by the Treasurer. The Club's current holdings of computer hardware and software were reviewed and the inventory of these items updated.

Work commenced on an electronic version of Council's policies manual. Records of decisions, originally recorded in the minutes, are to be transcribed into a data file from which specific items may be retrieved using the search capabilities of a word processing package.

Several Club members volunteered to participate in the development and management of a web site for the Club. The site, launched in the spring of the year, features information provided by various Club committees. The web site serves to inform both Club members and the general public, of Club activities, provides educational material relating to nature, showcases Club publications and promotes interest in membership of the Club.

ALAN GERMAN

Conservation Committee

The Committee represented the Club on a variety of conservation and policy issues. In particular:

- by participation in the review of the environmental policies of the Regional Municipality of Ottawa-Carleton Official Plan which was implemented in September 1997.
- by participation in the Canadian Museum of Nature Round Table to prepare an Environmental Stewardship Plan for the Museum's Collections and Research facility in Aylmer, Quebec.
- by assisting the City of Ottawa with the creation of a Greenway System Management Plan and with the ongoing Natural and Open Systems Study (NOSS).

The Committee submitted written and oral briefs to the "Lands for Life" planning process for Ontario; a process that is likely to have far-reaching consequences as early as the Spring of 1998. Various submissions were also made to the National Capital Commission as well as local and regional municipalities in the Ottawa-Hull area, to advocate the protection of such resources as Gatineau Park and the Greenbelt lands. The Club and its allies continue to oppose the urban development that threatens the Leitrin Wetland.

MICHAEL MURPHY

Education & Publicity Committee

Six major events were attended: the Ottawa Boat and Sportsman Show, the Ottawa Spring Home Show, the Carleton Teachers Federation Conference, an Environmental expo at Statistics Canada, the Greenway Exposition, and National Wildlife Week at Carlingwood shopping centre. In addition, the Committee provided judges and prizes for the annual Science Fair. Several trip leaders were provided for short outings and slide show presentations to such groups as Scouts Canada and an "Adopt a Riverbank" group. About 25 volunteers participated in these events. The Club's presence on the National Capital FreeNet was maintained.

TOM REEVE

Excursions & Lectures Committee

The Committee made arrangements for a total of 45 outings in 1997. Eighteen of these were designed to study birds, six to study plants, four to study insects, individual trips to study amphibians, fish, fungi, geology, and astronomy, and twelve trips of a general nature. The bird outings included two major and popular excursions to Presqu'île and Point Pelee. The program also included nine regular monthly meetings at the Canadian Museum of Nature, two workshops dealing with owls and migrant birds, and one miscellaneous lecture on the hidden world of birds. In June, OFNC members also participated in the EcoFair at the Fletcher Wildlife Garden and the BioBlitz, an attempt to

create a biological checklist for a selected area in Ottawa. The Annual Soiree was held as usual at the end of April.

PHILIP MARTIN

Executive Committee

The Executive Committee did not meet in 1997.

DAVE MOORE

Finance Committee

The Committee met once in 1997 and recommended no change in the Schedule of Dues and Fees.

COUNCIL

Fletcher Wildlife Garden Committee

Approximately 1500 hours of volunteer time were contributed in 1997, with most of it devoted to planting and maintenance of the backyard garden. Gillian Boyd did a terrific job delineating the beds, adding plants and improving full-season attractiveness. The Scouts did another planting in the new woods, volunteers did plantings in the hedgerow and the new woods, and Spring wildflowers, young Sugar Maples, Black Cherry, Basswood, and Beech trees were added to the old woods. Four habitat managers are now overseeing the garden operations including Sandra Garland (Old Woods), Claudia Burns (Backyard Garden), Christine Hanrahan (Hedgerow), and Jeff Harrison (New Woods).

Major events in the 1997 program included Earth Day, the Taverner Cup Competition, Migratory Birds Day, an Environment Fair, a plant exchange held jointly with the Canadian Wildflower Society, a garage sale, and participation in the Canadian Cancer Society Garden Tour.

The Centre is now regularly used for meetings of the Council, its Committees, and the local chapter of CPAWS. In October the Ottawa Valley Chapter of the Canadian Wildflower Society was invited to use

the Centre as a base for its meetings and activities. The Reference Library at the Centre has been expanded through direct purchases (approx \$1000), and donations from Club members. Agriculture Canada has installed a new and improved heating system. New information pamphlets and brochures are in preparation.

Major sources of revenue came from the Club grant, Friends of the Farm, Consumers Gas, the garage sale, private donations, and the Taverner Cup.

JEFF HARRISON

Macoun Field Club

The Committee met five times during the year to plan the weekly programs for the children and young people of the Macoun Field Club. In addition to regular indoor meetings and field trips during the school year, there were also camping trips for the High School students. A membership gap in the middle age group required that it be temporarily merged with the youngest group.

BARBARA GAERTNER

Membership Committee

The distribution of memberships for 1997 is shown in the table (below), with the comparable numbers for 1996 in brackets.

Two members were awarded Honorary Membership in the Club: Bruce Di Labio for his contribution to the Club's interest in birds and birding, and William O. Pruitt Jr. for his long-time contribution as an associate editor of *The Canadian Field-Naturalist*. Unfortunately this year, the Club lost Harold A. Senn a member since 1939, Pauline Snure an Honorary Member and member since 1941, and Nicholas Polunin a member since 1946. The Club also belatedly realized that Hugh M. Raup an Honorary Member and member since 1944 passed away in the Summer of 1995.

Membership of The Ottawa Field-Naturalists Club, 1997.

(subscriber totals not included, see *The Canadian Field-Naturalist* 112(2):354: Table 1.).

Type	CANADIAN		FOREIGN		Total
	Local	Other	USA	Other	
Family	346 (359)	20 (22)	4 (4)	0 (0)	370 (385)
Honorary	13 (13)	10 (9)	1 (1)	0 (0)	24 (23)
Individual	371 (403)	132 (136)	23 (23)	3 (3)	529 (565)
Life	16 (15)	19 (20)	4 (4)	2 (2)	41 (41)
Sustaining	10 (9)	2 (1)	0 (0)	0 (0)	12 (10)
Total	756 (799)	183 (188)	32 (32)	5 (5)	976 (1024)

Pat (Mickey) Narraway, Chairperson of the Membership Committee for the past five years and author of the computer software that supports the administration of the Membership Committee, was forced to retire from the Committee this year due to ill health.

DAVE SMYTHE

Publications Committee

The Committee oversees and advises Council on all aspects of the Club's publications. It met once in 1997.

Five issues of *The Canadian Field-Naturalist* were published in 1997: Volume 110, Issue 4, and Volume 111, Issues 1–4. This brings the *CFN* completely up to date and marks the first time in many years that Issue 4 of the current year has been mailed to the membership before December. The Committee commends Francis Cook for this achievement. The five published issues contain 940 pages: 57 articles; 48 notes; 7 COSEWIC articles; 113 book reviews; 325 new titles; 1 commemorative

tribute; and 65 pages of News and Comment. Included in the latter were two symposium papers (35 pages) and one paper (5 pages) on the threat to native species from introduced species. Volume 111, Issue 1, was a Special Issue "The Orchids in the Ottawa District" of 168 pages by Joyce and Alan Reddoch. All of the Associate Editors accepted reappointment in 1997.

Volume 31 of *Trail & Landscape* was published in four issues that contained 172 pages. For many years articles related to birds have dominated the year's volume but in 1997 the number of articles on flora was almost twice as many as those on birds, comprising about 30% of the volume.

Publication of *The Butterflies of Canada*, authors P. Hall, D. Lafontaine, and R. Layberry, to which the OFNC has contributed financially, was originally expected in 1997, but has been delayed until 1998. The National Research Council of Canada has joined with the University of Toronto Press as co-publisher.

RONALD BEDFORD

The Ottawa Field-Naturalists' Club Financial Statements: for the year ending 30 September 1997

Auditor's Report

To: The Members of THE OTTAWA FIELD-NATURALISTS' CLUB:

I have audited the balance sheet of The Ottawa Field-Naturalists' Club as at September 30, 1997, the statement of changes in net assets, and the statements of operations. These financial statements are the responsibility of the organization's management. My responsibility is to express an opinion on these statements based on my audit.

Except as explained in the following paragraph, I conducted my audit in accordance with generally accepted auditing standards. Those standards require that I plan and perform an audit to obtain reasonable assurance whether the financial statements are free of material misstatement. An audit includes examining evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation.

In common with many non-profit organizations, The Ottawa Field-Naturalists' Club derives some of

its revenue from memberships, donations, and fund raising activities. These revenues are not readily susceptible to complete audit verification, and accordingly, my verification was limited to accounting for the amounts reflected in the records of the organization.

In my opinion, except for the effect of the adjustments, if any, which I might have determined to be necessary had I been able to satisfy myself concerning the completeness of the revenues referred to in the preceding paragraph, these financial statements present fairly, in all material respects, the financial position of the OFNC as of September 30, 1997, and the results of its operations and changes in net assets for the year then ended in accordance with generally accepted accounting principles.

JANET M. GEHR
Chartered Accountant

North Gower, Ontario
24 September 1998

**The Ottawa Field-Naturalists' Club
Balance Sheet
September 30**

	<u>1997</u>	<u>1996</u>
ASSETS		
CURRENT		
Cash (Note 1).....	\$ 10,035	\$ 18,045
Marketable securities (Note 2).....	195,857	225,639
Accounts receivable.....	16,264	14,904
Prepaid expenses	1,608	1,608
	<u>223,764</u>	<u>260,196</u>
CAPITAL ASSETS (Note 3) .	-	-
LAND - Alfred Bog	3,348	3,348
	<u>\$227,112</u>	<u>\$263,544</u>
LIABILITIES AND FUND BALANCES		
CURRENT		
Accounts payable and accrued liabilities	\$ 14,019	\$ 12,675
Deferred revenue	12,361	13,836
	<u>26,380</u>	<u>26,511</u>
LIFE MEMBERSHIPS.....	7,475	7,000
	<u>33,837</u>	<u>33,511</u>
NET ASSETS		
Club reserve.....	100,000	100,000
Seedathon	1,405	965
Anne Hanes memorial	870	870
de Kiriline-Lawrence	21,892	15,432
Alfred Bog	531	451
Unrestricted	68,577	112,315
	<u>193,275</u>	<u>230,033</u>
	<u>\$227,112</u>	<u>\$263,544</u>

**The Ottawa Field-Naturalists' Club
Statement of Operations - OFNC
For the year ended September 30**

	<u>1997</u>	<u>1996</u>
REVENUE		
Memberships.....	\$ 13,667	\$ 14,879
T&L Subscriptions and Back Issues.....	274	186
Interest.....	1,501	2,626
Other Sales	779	3,268
Special Publications	-	366
	<u>16,221</u>	<u>21,325</u>
EXPENSES		
OPERATIONS EXPENSES		
Affiliation fees	1,104	2,193
Computer.....	3,026	2,295
Membership	79	1,677
Office assistant.....	1,333	1,012
Operations	5,515	3,584
OFNC GST (after rebate).....	2,309	778
	<u>13,366</u>	<u>11,539</u>
CLUB ACTIVITY EXPENSES (Income) - Net		
Awards	463	187
Soiree	534	(191)
Birds	663	327
Conservation	-	280
Education and Publicity ...	615	1,337
Excursions and Lectures .	(1,111)	(21)
Fletcher Wildlife Garden (Note 4)	(3,459)	1,237
Macoun Club.....	1,209	969
Trail & Landscape.....	10,328	8,733
	<u>9,242</u>	<u>12,858</u>
	<u>22,608</u>	<u>24,397</u>
DEFICIENCY OF REVENUES OVER EXPENSES.....	\$ (6,387)	\$ (3,072)

**The Ottawa Field-Naturalists' Club
Statement of Operations - CFN
For the year ended September 30**

	<u>1997</u>	<u>1996</u>
REVENUE		
Memberships.....	\$ 9,603	\$ 9,878
Subscriptions.....	<u>25,278</u>	<u>28,821</u>
	34,881	38,699
Reprints.....	10,034	9,002
Publications.....	24,954	17,270
Back numbers.....	20	316
Interest and exchange.....	8,465	12,429
Donations.....	<u>450</u>	<u>-</u>
	43,923	39,017
	<u>78,804</u>	<u>77,716</u>
EXPENSES		
Publishing.....	81,643	67,534
Reprints.....	7,609	5,306
Circulation.....	7,714	5,646
Editing.....	3,336	2,411
Office assistant.....	4,667	5,428
Office supplies.....	1,791	2,509
Advertising.....	-	84
Honoraria.....	6,300	4,500
CFN GST (after rebate) ...	<u>6,487</u>	<u>2,313</u>
	119,547	95,731
DEFICIENCY OF REVENUES OVER EXPENSES (Note 5) ..	<u>\$(40,743)</u>	<u>\$(18,015)</u>

**The Ottawa Field-Naturalists' Club
Summary of Significant Accounting Policies
September 30, 1997**

Nature of Business:

The organization is non-profit and incorporated under the laws of Ontario (1884). The organization promotes the appreciation, preservation and conservation of Canada's natural heritage; encourages investigation and publishes the results of research in all fields of natural history and diffuses information on these fields as widely as possible. It also supports and cooperates with organizations engaging in preserving, maintaining or restoring environments of high quality for living things.

Financial Instruments:

The organization's financial instruments consist of cash, accounts receivable, marketable securities, accounts payable. Unless otherwise noted, it is management's opinion that the organization is not exposed to significant interest, currency or credit risks arising from these financial instruments. The fair values of these financial instruments approximate their carrying values, unless otherwise noted.

Capital Assets:

Capital assets acquired after 1989 are expensed. Capital assets acquired prior to 1990 were recorded at cost and amortized on a straight-line basis. The assets have been fully amortized at year end.

Statement of Changes in Financial Position:

A statement of changes in financial position has not been provided as it would not provide additional meaningful information.

Foreign Currency:

Transactions during the year in U.S. dollars have been converted in the accounts to Canadian dollars at the exchange rate effective on the transaction date. All monetary assets in U.S. dollars have been converted to Canadian dollars at the exchange rates in effect at September 30, 1997. Gains or losses resulting therefrom are included in the determination of deficiency of revenue over expenditures for the year.

The Ottawa Field-Naturalists' Club Statement of Changes in Net Assets								
For the year ended September 30						1997	1996	
	Club Reserve	Seedathon	Anne Hanes Memorial	de Kiriline-Lawrence	Alfred Bog	Unrestricted	Total	Total
Balance, beginning of year	\$ 100,000	\$ 965	\$ 870	\$ 15,432	\$ 451	\$ 112,315	\$ 230,033	\$ 248,099
Deficiency of revenues over expenses - OFNC	-	-	-	-	-	(6,387)	(6,387)	(3,072)
Deficiency of revenues over expenses - CFN	-	-	-	-	-	(40,743)	(40,743)	(18,015)
Donations	-	-	-	-	-	3,392	3,392	3,551
Contributions	-	440	-	6,460	80	-	6,980	(530)
Balance, end of year	\$ 100,000	\$ 1,405	\$ 870	\$ 21,892	\$ 531	\$ 68,577	\$ 193,275	\$ 230,033

The Ottawa Field-Naturalists' Club Notes to Financial Statements						
September 30, 1997						
1. Cash						
					1997	1996
Chequing					\$ 482	\$ 10,154
Savings					5,708	7,638
Savings - U.S. dollar					(6)	(6)
Fletcher Wildlife Garden					3,851	259
					<u>\$ 10,035</u>	<u>\$ 18,045</u>
2. Marketable Securities						
					1997	1996
	Fair Value	Maturity Value	Maturity Date	Yield	Carrying Value	Carrying Value
Short Term						
GIC - 00019	\$ -	\$ 24,404	07-10-97	2.125 %	\$ 24,394	\$ 23,831
GIC - 00094	-	17,306	26-01-98	2.125 %	17,188	-
GIC - 00108	-	18,502	24-10-97	2.250 %	18,475	-
Long Term						
GIC - 00019	-	37,301	28-04-98	3.000 %	37,776	36,476
GIC - 00027	-	-		- %	-	36,130
GIC - 00035	-	-		- %	26,064	36,096
GIC - 00043	-	26,186	09-12-97	2.500 %	20,664	25,315
Strip bond Prov. of British Columbia	-	-		- %	-	33,501
Strip bond Prov. of British Columbia	37,022	37,285	21-12-97	8.056 %	36,539	34,290
Strip bond Prov. of British Columbia	35,335	37,592	23-02-99	4.362 %	35,421	-
	<u>\$ 72,357</u>	<u>\$198,576</u>			<u>\$195,857</u>	<u>\$225,639</u>

The carrying values for the guaranteed investment certificates (GIC's) and strip bonds are stated at cost plus accrued interest.

The Ottawa Field-Naturalists' Club
Notes to Financial Statements *cont'd*

September 30, 1997

3. Capital Assets

	1997			1996		
	Cost	Accumulated Amortization	Net Book Value	Cost	Accumulated Amortization	Net Book Value
Equipment	\$ 16,748	\$ 16,748	—	\$ 16,748	\$ 16,748	—

4. Fletcher Wildlife Garden

	1997	1996
Revenue	\$ 6,559	\$ —
Operating expenses	1,220	1,237
Maintenance expenses	1,880	—
Excess (deficiency) of revenue over expenses	\$ 3,459	\$ (1,237)

5. Deficiency of revenue over expenses - CFN

The CFN operating deficiency for the current fiscal year was a result of publication of two special issues for which no revenue was received. The publication of these issues was approved by the Board of Directors.

6. Comparative Amounts

In certain instances, 1996 amounts presented for comparative purposes have been restated to conform to the financial statement presentation adopted for the current year.

A Tribute to Hugh Miller Raup, 1901–1995

WILLIAM J. CODY

Biological Resources Program, Eastern Cereal and Oilseed Research Centre, Agriculture and Agri-Food Canada, Central Experimental Farm, Ottawa, Ontario K1A 0C6.

Cody, William J. 1998. A tribute to Hugh Miller Raup, 1901–1995. *Canadian Field-Naturalist* 112(3): 557–564.

Hugh Raup was born 4 February 1901 in Springfield, Ohio, the son of Gustavus and Fannie Raup. He died at Sister Bay, Wisconsin, 10 August 1995. His early education was in public schools and Wittenburgh College at Springfield. He and Lucy Gibson were married 20 June 1925 and were the parents of two sons, Karl and David.

The following Memorial Minute for the Faculty of Arts and Sciences of Harvard University dated 8 April 1997 was composed by David R. Foster, Director, Harvard University Harvard Forest, Petersham, Massachusetts, together with committee members P. Barry Tomlinson, Peter Ashton and Rolla Tryon.

“Hugh Miller Raup was among the last of Harvard’s great field naturalists — a botanist, ecologist and geographer who vigorously applied his immense experience in tropical, temperate and arctic landscapes to landmark studies in natural history and natural resource management. As a teacher, colleague and friend he inspired students and contributed to Harvard and the broader world to the end of his 94 years.

“Hugh Raup’s childhood and early experiences shaped his career and figured prominently in his classic paper on the land-use history of the New England landscape, “The View From John Sanderson’s Farm”. Born February 4, 1901 to Gustavus Phillip and Fannie (Mitchell) Raup, Hugh roamed the family farm of Springfield, Ohio and explored the natural and agricultural world of the mid-west. At Wittenberg College he received his A.B. in 1923, along with an introduction to geography from Charles Shatzer who exposed Hugh to geomorphic processes, the cultural forces that shape nature, and a broad temporal perspective on landscape change. Upon graduation, Hugh was appointed as Instructor in Biology and, following receipt of his A.M. degree in 1925 and Ph.D. in 1928 from the University of Pittsburgh, promoted to Assistant Professor at Wittenberg, where he taught until his departure to Harvard in 1932.

“At Harvard, Hugh Raup was associated with four botanical institutions: the Arnold Arboretum, where he served as Research Assistant and Associate from 1932–38; the Black Rock Forest where he conducted research for many years; the Department of Botany, where he held appointments as Assistant Professor in Plant Ecology, Associate Professor in Plant Geography, Professor of Botany and Bullard Professor in Forestry; and the Harvard Forest where he was Director from 1946 to 1967. His passion for geomorphology generated strong ties with the Department of Geography, collaborations with Kirk Bryan in the Geology Department and a position as Visiting Professor at Johns Hopkins University for three years after retirement from Harvard in 1967. Subsequently, Hugh and Lucy Raup lived for more than 20 years on the Common in Petersham, Massachusetts where Hugh maintained vigorous correspondence with colleagues and challenged emerging scientific minds with his frequent, lengthy letters. In their last years Hugh and Lucy moved to Wisconsin to be near their son Dave. Hugh was predeceased by his elder son Karl.

“Hugh’s training in biology and geography and desire to synthesize geological and evolutionary processes in his understanding of natural ecosystems, generated unique contributions to the fields of plant geography, ecology, forestry and natural resources. Beginning with his doctoral research on the vegetation and floristics of the Athabaska-Great Slave Lake Region of Northwestern Canada, Hugh commenced a life-long pursuit documenting the plants and environment of the far north. During subsequent years collaborating with the Canadian National Museum, these studies led Hugh, his family and many colleagues from the boreal forests of Alaska, through subarctic Canada, to the high Arctic of Mesters Veg in northeastern Greenland. Around campfires in the glow of northern summer evenings Hugh and Lucy would undertake the meticulous documentation of field collections that form the basis of all biogeographical study. These summer-long excursions produced a stream of publications describing the systematics and distribution of plants ranging



Hugh Raup relaxing at his home in May 1979 (photo by George Argus).

from ferns, fungi and lichens to conifers, characterizing vegetation patterns, and analyzing the soils, environment, and geomorphology that control ecosystems at high latitudes.

"As Hugh was immersed in his northern studies, ecologists became embattled in arguments concerning the stability of the environment and vegetation, the organization of biotic communities, and the relative importance of disturbance in regulating ecosystem process. One established view held that equilibrium conditions were the norm, that vegetation developed progressively through a process of "succession" towards relatively stable communities, and that disturbances were rare. This view provided a simple framework for interpreting past changes, predicting future ones, and relating spatial patterns of vegetation to temporal sequences. However, based on his familiarity with the importance of processes in natural ecosystems disturbance and an evolutionary understanding of biological species, Hugh developed alternative notions that shaped his future work and comprised one of his major contributions to ecological science.

"Through the course of his career, Hugh's interests broadened beyond plant biology to embrace such topics as Indian archaeology, the role of frost action, lake-level change and winter injury in northern ecosystems, and the influence of natural disturbance and historical land use on forests in Cuba, Honduras, and New England. At the Harvard Forest his tenure as Director, and the studies of his students and colleagues, provided a natural transition between the early research in silviculture and ecological forestry by Richard Fisher and the broad-scale ecosystem work that figures prominently into the current Long Term Ecological Research Program.

"Hugh Raup revelled in his role as contrarian and outspoken critic of conventional wisdom and he exported this role from the classroom and academic setting to the world of natural resource management and public education. One member of this committee recalls that Hugh's lively course in plant geography was the very best that he attended as a graduate student and that it attracted students from across the scientific disciplines. With faculty and staff from the Harvard Forest and Business School Hugh conducted an annual series of Conferences on Forest Production that incorporated lessons from economics, land-use studies, geography, and the management history of the Harvard Forest and Northeastern U.S. to address the needs of resource and policy managers

from federal agencies, industry, and government. In his popular lecture and article on John Sanderson's farm Hugh taught his message of change, unpredictability of natural and human systems, and ecosystem resilience. It was a lesson well-learned by students of all ages.

"Hugh's personal charm, his delightful habit of challenging new as well as established ideas, and his insights drawn from diverse ecosystems made him an exceptional mentor, colleague and friend. His work and ideas continue to challenge new scientists and provide a legacy to the institution that served as his home for nearly 40 years. With a tap and fuss at his pipe Hugh always mused carefully over one's remarks and reciprocated with thoughtful and provocative comments."

Hugh's Canadian studies were mainly in the northwest. His work in the Athabaska-Great Slave Lake, Wood Buffalo National Park and the Peace and Upper Liard River regions began in 1926 and continued through the summers of 1927, 1928, 1929, 1930, 1932 and 1935. This was the pre-air travel time when movement throughout the area was by steamboat, motor tug, canoe or skiff, pack-horse, wagon or buckboard and by back packing. This meant that food, tents, extra clothing, blankets, plant presses and other equipment had to be portaged through sunshine, wind, rain, mosquitoes and black flies. On many of the excursions Hugh was accompanied by his wife Lucy, who had a particular interest in mosses and lichens. In the Lake Athabasca region, at least, the Raups travelled by freighter canoe with their two young children, David and Karl. In addition to collecting lichens and mosses, Lucy looked after the two boys, and was camp cook.

Based on about 20 years of field camping, mostly in connection with Hugh's research, Lucy published *Camper's Cookbook* (Charles E. Tuttle Co., Rutland, Vermont, 1967).

The results of this field work and much related research created, among other smaller publications, four extensive efforts: *Phytogeographic Studies in the Peace and Upper Liard River Regions, Canada* (1934), *Botanical Investigations in Wood Buffalo Park* (1935), *Phytogeographic Studies in the Athabaska-Great Slave Lake Region I. Catalogue of the Vascular Plants* (1936), II (1946), and *The Lake Athabasca sand dunes of northern Saskatchewan and Alberta, Canada* (Raup and Argus 1982).

In 1939 Hugh, again accompanied by his wife Lucy, together with his graduate student James (Jim) H. Soper, extended his work northward into the District of Mackenzie in the vicinities of Fort Simpson at the junction of the Liard and Mackenzie



Hugh and Lucy Raup with their sons Karl (left) and David (right) in the mountains adjacent to Brintnell Lake in western District of Mackenzie in 1939 (photo by Jim Soper).

rivers and Britnell Lake in the southern Mackenzie Mountains. This work resulted in the publication of *The Botany of Southwestern Mackenzie* (1947).

These publications were not just annotated lists of species in parts of our northland, but included information on earlier explorers, geology and physiography, both glacial and pre-glacial, climate, geographic studies of the different vegetation patterns such as forests, prairies, sand bars and riverbanks, fields and clearings — all tremendous efforts. Indeed, all of this work increased the known distribution of many taxa and in addition added 24 taxa which he described: *Achillea megacephala*, *Alnus crispa* var. *elongata*, *Arnica snyderi*, *Braya henryae*, *Carex soperi*, *Cicuta mackenzieana*, *Deschampsia mackenzieana*, *Draba longipes*, *Euphrasia subarctica*, *Lychnis brachycarpa*, *Picea glauca* var. *porsildii*, *Poa brintnellii*, *Rosa acicularis* var. *cucurbiformis*, *Salix barrattiana* var. *marcescens*, *S. bebbiana* var. *depilis*, *S. brachycarpa* var. *psammophila*, *S. lasian-dra* var. *recomponens*, *S. silicicola*, *S. turnorii*, *S. tyrellii*, *Statice interior*, *Stellaria arenicola*, *Tanacetum huronense* var. *floccosum*. In addition, two species from this northwestern region have been named after him: *Gentiana raupii* A. E. Porsild, an endemic of the Mackenzie River Basin, and *Salix raupii* G. W. Argus, first known only from north-eastern British Columbia, but now also known from western Alberta, southwestern District of Mackenzie and southeastern Yukon Territory.

In *Rhodora* Volume 45 (pages 306–316, 1943) Anderson Bakewell published “Botanical collections of the Wood Yukon Expeditions of 1939–1941”.

Hugh Raup, over many years, accumulated an extensive collection of correspondence and other materials related to his studies ...

“On August 25, 1997 the Harvard Forest Archives mailed 35 boxes of the late Dr. Raup’s Arctic research and literature to the University of Alberta in Edmonton. [As of 12/1997 the total is 45 boxes.] The material included research notebooks, maps, photographs, and a number of reprints from Dr. Raup’s personal collection.

“The University of Alberta was chosen as the recipient of these materials after a careful search conducted by Harvard Forest Director Dr. David Foster and former Archivist Sarah Neelon. The Raup Arctic collection will be housed in the University Book and Record Depository, a state of the art building opened in 1994, and will be under the care of University Archivist Bryan Corbett. Most of the arrangements for the transfer were made through Dr. Merrill Distad, Assistant Director of Libraries for the University of Alberta.” [John Burk, 9 January 1997] All of his temperate and tropical materials and most of his correspondence have been placed in the Harvard Forest Archives, Petersham, Massachusetts.

The principle repositories of Canadian specimens collected by Hugh Raup are: Herbarium, Arnold Arboretum, Harvard University, Cambridge, Massachusetts (A); Gray Herbarium, Harvard University, Cambridge, Massachusetts (GH) and Herbarium, Research Division, Canadian Museum of Nature, Ottawa (CAN).

Hugh Raup was proposed for Corresponding Member of The Ottawa Field-Naturalists’ Club by

Hugh was responsible for the identifications of specimens which Anderson had collected in the St. Elias Range in southwestern Yukon Territory. This is probably what sparked Hugh to participate in expeditions to the Alaska Military Highway in 1943 and 1944. Publications by Hugh (1945) did not list the species collected adjacent to the new highway, but described with interesting detail, the various vegetation types through which it passed from prairie, wetlands and forests to alpine. All of his work in the northwest has provided basic information for future studies of botany and ecology in this most important region of Canada. Elsewhere in Canada he was involved in the identification of a large collection of plants by Dr. George M. Sutton in 1929 and 1930 from Southampton Island at the north end of Hudson Bay. This resulted in the publishing of *Pteridophyta* and *Spermatophyta* of Southampton Island (1936) which included 66 new records to the known flora of the island. Also in the northeast, Hugh published *The Willows of the Hudson Bay Region and the Labrador Peninsula* (1943). This was a tremendous effort with an introduction followed by keys to 40 species and a number of varieties and forms, extensive comments, citations of some 1700 specimens from various sources and distribution maps. Following his particular interest in the genus *Salix* he also published *The Willows of Boreal Western America* (1959). This most interesting study of over 60 species with an extensive introduction, keys, descriptions and comments was a tremendous step forward in the understanding of this most difficult genus in northwestern Canada.

Erling Porsild, seconded by Rand and accepted by the Council on 26 October 1944. In 1968, when he was the only Corresponding Member, Corresponding Memberships were absorbed within the Honorary Membership category and he became an Honorary Member because Ottawa Field-Naturalist Honorary Members no longer had to live in the Ottawa Region.

Two recent publications have highlighted Hugh Raup’s life: *Forests in the Here and Now*, A

Collection of the writings of Hugh Miller Raup, Bullard Professor of Forestry, Emeritus Harvard University (Edited by Benjamin B. Stout and published by The Montana Forest and Conservation Experiment Station, School of Forestry, University of Montana, Missoula, Montana 59812, 1981) and *John Sanderson's Farm, a perspective for the use of the land* republished in *Forest History Today* (1997 pages 2–11).

Acknowledgments

My thanks to Jim Soper and George Argus for providing the photographs, to George Argus for his contributions and comments on an earlier version, and to my daughter, Leslie Durocher for inputting this information on her computer.

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Book Reviews

ZOOLOGY

The Great Blue Heron: A Natural History and Ecology of a Seashore Sentinel

Robert W. Butler. 1997. UBC Press, Vancouver. 167 pp., 24 colour and 27 black-and-white photographs, 8 maps, 7 graphs, 1 sketch, 18 tables. \$39.95 Canadian.

Even the most casual of observers thrills to the sight of a Great Blue Heron, described as a "seashore sentinel" in two respects. First, an individual heron stands guard over a patch of shoreline. Second, the species as a whole is equally "a sentinel of the changes we humans have brought to the coastal environment." Robert W. Butler brings his years of experience with this ungainly yet beautiful bird in a well-organized and well-illustrated book, packed with information. He deals almost exclusively with the coastal subspecies of the Pacific Northwest, *Ardea herodias fannini*.

Complicated courtship displays are described; the heron bill turns bright yellow during courtship, but fades soon thereafter. Territorial behaviour is under control of testosterone and incubation behaviour is controlled by prolactin. At fledging the male is 12% heavier than the female, but later adults are of equal weight. Each chick consumes 2000 kilojoules of food per day between 26 and 41 days; they remain in the nest until two months old. Only 16% of early-nesting, but 60% of late-nesting pairs fail to raise any young.

Nature's bounty includes 52 species of fish in eelgrass (up to 12 million individuals in 31 hectares) and results in high heron population concentrations near the Fraser River delta. Up to 300 herons will

gather in such a meadow, where one heron can catch a fish every two minutes and meet its daily food requirements in an hour. But in the fall, when fish numbers have diminished, juvenile herons are inefficient at catching fish and are forced upland to hunt for voles. Some starve.

The largest heron colonies, sadly, coincide with one of Canada's fastest-growing human populations and consequent habitat destruction. Though some colonies, as in Stanley Park, have adapted, mere presence of a human walking below the nests may cause herons to leave their nests; crows and ravens may then take the eggs. Bald Eagles kill heron chicks, and eagles are increasing in numbers. Graphs predict a decline in heron numbers simply as human disturbance increases; this process will be hastened if private land on which colonies reside is sold for development, and if pollution increases.

The maps are attractive, yet my only annoyance was to find that five sites mentioned in the text were omitted from the maps. This book is written in a non-technical style, so should be of interest to birders, sportsmen and to those members of the general public who are fascinated by this largest of all herons.

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The Science of Overabundance: Deer Ecology and Population Management

Edited by W. J. McShea, H. B. Underwood, and J. H. Rappole. 1997. Smithsonian Institution Press, Washington, D. C., 402 pp., illus. U.S. \$37.50.

The concept of overabundance is often based on a value judgement, rather than on biological reality; this can be challenging for wildlife scientists and managers trying to work from a biological basis. A major objective of this book is to clarify overabundance as it relates to North American *Odocoileus* deer. In short, are deer actually overabundant? If so, what effects do overabundant deer have on ecosystems?

The volume is based on a symposium, and as with many proceedings, it is a diverse collection of papers (23 in total). My initial thought was that this diversi-

ty worked against the objective of clarifying the concept of overabundance. At the book's outset, McCabe and McCabe (Chapter 2) reconstruct historic deer abundance and state that there is no good evidence that White-tailed Deer are more abundant in North America now than prior to European settlement. After this surprising suggestion, subsequent authors list numerous consequences of overabundant White-tailed Deer. This apparent contradiction does little to clarify the dogma and politics around the term overabundant. Not until the epilogue (Sinclair, Chapter 23) does the puzzle fall together. Sinclair does an excellent job of relating overabundance to carrying capacity. He suggests that various authors in the book are operating with different concepts for

carrying capacity (e.g., ecological, cultural, timber-harvesting, hunting); the results are value-based decisions about whether or not deer are overabundant. Sinclair points out that there are two separate types of problems: (1) those associated with biology; and (2) those associated with value judgements. Observers from different perspectives can have completely different perceptions of overabundance. This is the central message of the book. It is worth noting that there are actually few situations documented where White-tailed Deer are biologically overabundant (e.g., in heavily fragmented woodlands where abnormally high nutrition is available as agricultural crops; i.e., the fragmentation-nutrition hypothesis).

With Sinclair's epilogue in mind, I can look back on many chapters favourably. The book has three major sections: (1) philosophical perspectives on managing deer; (2) population effects of high-density deer herds; and (3) ecosystems and high-density deer herds. Within each section there is a broad range of topics from many well-established scientists. Much of the material is research from the central part of the White-tailed Deer's geographic range (eastern United States) but the book has more broad-reaching applications. The book takes an unusual approach by asking what effects do deer have on ecosystems and protected areas. Consequently, there

are chapters about the effects of deer on: songbirds, hemlock forests, oak forests, old-field plants, and bottomland forests. In addition there are excellent chapters on zoonotic diseases and deer health characteristics.

The book fits well with two other, recent volumes about deer overabundance (McAnich 1995; Warren 1997). In fact, Warren (1997) was published after McShea et al. (1997) and Warren states that an objective of *The Wildlife Society Bulletin* special issue was to augment the previous work. *The Science of Overabundance* is an attractive, hard cover volume. I recommend it to all wildlife managers and to interested ecologists and naturalists.

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The EBCC Atlas of European Breeding Birds

Edited by W. J. M. Hagemeijer and M. J. Blair. 1997. T & A D Poyser, London. cxli plus 903 pp., illus. £55. [EBCC stands for European Bird Census Council]

One has to be impressed with a book where the seven-page introduction has 14 languages and two alphabets. The indices are in 15 languages; 14 plus Latin or scientific names. The book is indeed a remarkable achievement involving writers from 37 countries and artists from 11 countries. To succeed they had to overcome such barriers as language, finances, politics, available skills, and transportation. During the twenty-five years or so it required to collect and publish the data, Europe has experienced many major political changes, which must have altered working relationships profoundly. Simply getting this book into print is a wonderful achievement of international cooperation.

The heart of the book, the species accounts are about 75% of the text and follow the same type of format as other breeding bird atlases, especially the British ones. For each account there is a small, high-quality line drawing of the species under discussion, its common name in all 14 languages and an evaluation of its distribution and status. Most species have a map that graphically depicts the results of the field

work using dots to indicate where the species breed. For those places that have quantitative data, the population density is shown by the size of the dot. Histograms show the population size for the ten most important countries (unless it occurs in less than ten). A pie chart shows, by colour code, the proportion of countries for which the population is rising, falling, or staying stable.

An interesting example of a species account is that of Ruddy Duck. This bird first escaped from British ornamental collections in 1953. By 1991 it had risen to 570 feral breeding pairs. It has slowly spread to neighbouring countries and even has a small migratory population. In Spain it cross breeds with the White-headed Duck. This latter species is confined to Spain and, at 70 breeding pairs, is considered endangered. So 14 pure and 33 hybrid Ruddy Ducks had been shot by 1993 to control this "pest." It is difficult for me to view this colourful duck with its charming clockwork-toy courtship as vermin!

The remainder of the book is divided into sections covering the introduction, atlas history, conservation, acknowledgements, and bibliography. Perhaps the most interesting of these sections, from a North American perspective, is a brief evolutionary history of

Europe's bird fauna. I also liked the derived maps. In the first use of the atlas data the authors have derived a set of maps to show species richness by locality and the distribution of the various species at risk.

During my first rummage through the book, one fact became clear. Great Britain is not a key breeding ground for most species. Being a long time member of Britain's RSPB [Royal Society for the Protection of Birds] and, reading the coverage of increased breeding successes in their excellent magazine, has clearly given me a bias. Time and again, Spain, Belarus, Ukraine, and Romania outstrip all others in the population histogram. All these are countries long repressed by dictators and are now pushing free market reforms. What does this imply for Europe's birds? At least there is now a single document, this book, on which to base an understanding of change.

I noted with interest that many accounts were sponsored (I presume this means "paid for"). For example, the Avocet page is sponsored by the RSPB; fitting since it is their symbol. Other pages are sponsored by individuals and nature societies, and there are even some industrial company sponsors. While I expected a company like Swarovski, a binocular manufacturer, to be involved, I was pleased to see more commercial organisations like Celbi and Stora taking part. Each organization has its logo tastefully displayed at the bottom of the page.

After all the effort needed to bring this book into print, I am disappointed by some details of the book's production. The colour codes for the population histograms and pie charts are on the dust cover. Dust covers can get lost or damaged, especially on a well-used book. I have colour photocopied the code section and glued it permanently to the rear of the book. (I also made a book mark of the code to use as a direct comparison). The colours used to code the maps are the same as used in the population charts, but with different meanings. This is not a major point, but I would have preferred them to have used different ones. More of a problem is the actual choice of colours. Colour selection includes dark and light purple, "red" (actually brown like a Wood Thrush's head), orange, and grey to denote the breeding status. I think a more coordinated colour grouping (for example, purple through blue) would be visually more pleasing and provide a better sense of the breeding distribution. Grey was used to denote

areas which were not covered and areas which were surveyed but the species in question could not be found were left blank. Logically and, again visually, it makes sense to reverse these code colours. The "red" — orange series of dots indicate quantitative data, measuring from half millimetre to two mm in six steps. Differentiating between dots is a little difficult. The purple colours represent qualitative data so are uniformly sized at about 1.25 mm. So a tiny red dot (one — nine pairs) can appear alongside a larger (equivalent to 1000 - 9999 pairs) purple qualitative dot. This also leads to a false visual impression. For example, the Egyptian Vulture's tiny quantitative dots along the Pyrenees represent good quality data. These are almost lost in the flood of uniformly-sized purple dots (probable breeding) that cover much of the rest of Spain.

I had a number of problems when I tried to use the data. The population histograms claim to represent "population." By comparison with the population data given in the text it became clear the authors meant breeding pairs. I searched the introductory text to see if this was stated, but could only find inferences to support my conclusion. I do not agree with this use of "population." While it is simple to double the breeding pair number, it would not account for the non-breeding birds. In some species the non-breeding individuals are a significant portion of the population. The pie chart data is also confusing. For example, take the case of Audouin's Gull, a bird which breeds in four countries. The status is different in each, so the pie chart is divided into four equal sections. One quarter section is for Spain where 80% of these gulls breed, giving a distorted visual significance to the other minor breeding places.

This book, once you have adapted to its quirks, is not just a good book; it is an important book. For the first time it puts whole bird *populations*, unconfined by arbitrary human boundaries, into focus. This must influence decision making on environmental issues. Only time will tell just how profound this influence will be. Let us hope, for the bird's sake, that the spirit of cooperation forged by this book among scientists will spread to European political circles.

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BOTANY

The Ferns and Allied Plants of New England

By Alice F. Tryon and Robbin C. Moran with photographs by Robert L. Coffin. 1997. Center for Biological Conservation, Massachusetts Audubon Society, Lincoln, Massachusetts. xv + 325 pp., illus. U.S. \$49.95 + shipping.

The six New England States in northeastern United States, Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont, are surrounded by Quebec and New Brunswick in the north, New York on the south and west, and the Atlantic Ocean in the east. Their area of 66 608 square miles is only a small portion of the 3 022 387 square miles of mainland United States. In this relatively small area there are 92 native species of ferns and allied plants. This is a high number when compared to California, which has eighty-seven, Texas, which has 107 and Florida which is close to the fern-rich tropics and has 125 native species. Of the 92 species about one-third are restricted to eastern North America, seven extend southward into the American tropics, two extend southward to Central and South America, one southward to Guatemala, 10 occur in eastern Asia, two occur in eastern Asia and Europe, 10 are circumpolar and about one-third are circumboreal.

The presentation of these ferns and fern allies is excellent. There is an initial list of families, genera and species together with common names followed by a key to genera and then a General Plan of the Genetic Treatments. Each genus has at least a page devoted to it under the headings of Characteristics, Distribution, Chromosome Number, and Remarks. The latter section contains a myriad of most interesting comments. Each species has two pages devoted to it — on the left an excellent black-and-white photograph taken in the wild together with a small

world, wide map and a dot map depicting the New England States — on the right is the common name, scientific name with some synonymy, and again, Characteristics, Habitat, New England Range, World Range, Chromosome Number, Spores, and Remarks which are again extremely interesting. Generic keys are accompanied by excellent black frond shapes and line drawings of particular features such as sori, indusia, and stem characteristics in the genus *Equisetum*. It is of particular interest to know that the majority of the photographs of the ferns were taken mostly in the vicinity of Amherst, Massachusetts, by Robert L. Coffin, a naturalist and photographer about fifty years ago. His eye for this extremely interesting group of plants was most impressive, especially at a time when he had to carry a large 9 by 12 centimeter Zeiss Icon Maxima view camera together with a heavy wooden tripod into the woods and over the hills.

In the final pages of this volume are a series of Scanning Electron Micrographs of Spores, information on Geology and Climate, suggestions of Ferns for the Gardens, a glossary, references, and index.

The authors have not just given another book on ferns and fern allies of a small region but have produced a tremendous work which will be invaluable to teachers, their students, and naturalists not only in northeastern United States, but beyond. They are to be congratulated.

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Revised Checklist of New York State Plants

By Richard S. Mitchell and Gordon C. Tucker. 1997. Bulletin No. 490, New York State Museum, The University of the State of New York, The State Education Department, Albany, New York 12230, vii + 400 pp. U.S. \$16.50.

This volume contains a wealth of information not only for the possible publication of a new flora of New York State but also invaluable to all groups interested in natural history, conservation, and especially rare and endangered species in the state. The last publication of *A Checklist of New York State Plants* was by R. S. Mitchell in 1986. The present

publication in which the pteridophytes follow the format of *Flora of North America*, Volume 2 (1993) and the phylogenetic system for angiosperms is that proposed by Arthur Cronquist (1981), treats 2078 native and 1117 non-native species plus 84 native and 324 non-native extirpated or non-persistent species. In addition 171 native and 42 non-native plus 18 native and one extirpated hybrid are included together with 176 native and 33 non-native subspecies and varieties. Common names are provided for species primarily when they have been used in 20th century publications. Synonyms for species and

intraspecific taxa are listed following the accepted scientific names. Rarity status in New York State is provided as required.

In addition to the above, instructions are provided on how to use the work, a list of pertinent literature, indexes to common and scientific names, and, of particular interest, an alphabetical Appendix of Excluded Species which for each species has the reason for exclusion included.

Such a book as this gives one the hope that all the

states as well as the Canadian provinces and territories might each some day have a similar volume published.

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The Private Life of Plants: A Natural History of Plant Behaviour

David Attenborough. 1995. Princeton University Press, Princeton, New Jersey, USA. 320 pp.

Good science writing for the public is extremely difficult. Scientists who are good writers are a rare breed. In Sir David Attenborough we find a longtime and skilled practitioner of this art. I can remember reading *Zoo Quest to Madagascar* (published in 1961) when I was very young and watching in fascination an old black-and-white TV as Attenborough, dressed in safari gear, sat in the midst of a desert somewhere, piecing together fragments of shell to make an enormous egg and speculating that this extinct bird was the giant Roc of Arabian Nights legends. With time and new technology, Attenborough's communication skills have become more refined, yet he has never lost the ability to convey enthusiasm and fascination for natural history.

Attenborough is best known for his programs on zoology. But in this latest endeavour, he turns his attention to the world of plants. *The Private Life of Plants* continues a long tradition of books produced to accompany his TV series. Splendidly illustrated with dozens of colour photographs, this book is subdivided into six chapters ("Travelling", "Feeding and Growing", "Flowering", "The Social Structure", "Living Together", and "Surviving"), mirroring the structure of the TV series for which it is a companion volume.

Each chapter concentrates on a particular activity of plants. "Travelling" examines seeds and seed dispersal, the stage of most plants' life cycle when they can travel most easily. It surveys some of the ingenious ways in which plants enlist the witting or unwitting aid of animals and birds for transportation, by producing attractive fruits for example. "Feeding and Growing" highlights methods plants use to try to protect themselves from creatures that would feed on them, including a formidable array of camouflage, mechanical and chemical defences against predators. Attenborough points out that this warfare takes place

in a co-evolutionary fashion. As plants develop new defences, animals develop new ways of getting around them. Ultimately, all animal life is dependent, even at second or third hand, on plant food. Graphic images and descriptions show how some plants (pitcher plants, sundews, Venus' flytrap) have turned trapper and carnivore, deriving part of their nutrition from insects.

For palynologists like myself, the most interesting chapter covers pollination ("Flowering"). Although wind pollination is mentioned, most attention is paid to the complex interactions between plants and their animal, bird, or insect pollinators. This provides a very different perspective to the one I am used to from pollen records, where the majority of pollen types are from wind-pollinated plants. Attenborough describes how flower structure, including shape, colour, and scent, can be modified in a myriad of ways to accommodate different pollinators and how plants entice their preferred pollinators by offering nectar for instance. In some cases, the plant may be completely dependent on one species of insect for pollination. This must be an important consideration for those concerned with biodiversity and ecological integrity.

The "Social Struggle" begins with the great storm or hurricane that devastated much of England in October 1987. Attenborough shows that an event seen as a disaster for trees and forests was an opportunity for many other types of plants, especially those that thrive in forest clearings or gaps. Attenborough also explores the role of fire, not so much as a destructive agent, but as a positive influence in forest maintenance and regeneration.

"Living Together" focuses more explicitly on plant-animal and plant-insect interactions. Attenborough shows that these relationships often have benefits for both partners; plants get protection and sometimes nutrition, and insects get a home and a secure food supply. Attenborough turns his atten-

tion to less obvious relationships such as the partnership between mycorrhizal fungi and plants. The apogee of such symbiosis is lichen, an intimate association between fungi and algae. Attenborough surveys some of the multitudinous forms of lichen and emphasizes their importance as pioneering organisms in harsh environments. More sinister are plant parasites, deriving nutrition from other plants. The most spectacular of these is rafflesia and Attenborough includes a remarkable series of photographs showing one flowering, producing the biggest flower of any plant.

Extremes are the keynotes for "Surviving"—extremes of cold, of heat, of drought, or of moisture. Suitably, the chapter begins with a visit to the extreme ends of the earth, Antarctica and the Canadian Arctic, where Attenborough finds some plants that can survive even under the most severe conditions. At the equator on Mount Kenya, plants have to survive diurnal swings between extreme cold and heat. As a result, the mountain has developed its own unique flora. Similarly, on the tepuis of South America, drenched by torrential rainfalls, an astonishing range of endemics has developed, including many carnivorous plants. Attenborough estimates that the tepuis have 900 species of orchids, most of which are endemic. Then Attenborough explores the boundary between land and sea, where the mangroves reign, coping with salinity and instability.

This book is not written from a botanist's or taxonomist's viewpoint, but very much from the perspective of the natural historian. Latin binomials are confined to the index; plants are called by common names in the text. Botanic purists may "Harrumph!" in annoyance, but it probably makes the book accessible to a wider readership. As such, it is a book that can be enjoyed by anyone interested in natural history. Adults will enjoy the text; children will be fascinated

by the colour pictures. Despite its deceptively simple style, it is packed with information. From my own position, it would make great supplemental reading for an introductory course in palynology. Especially so, since many students come to palynology from varied backgrounds (geology, anthropology, geography), and sometimes have only the vaguest grasp of botany and the role of pollen in plant life-cycles. Often, getting students to understand that pollen grains aren't seeds can be a herculean endeavour!

The appeal of this book undoubtedly lies in its very personal view of the world of plants. Attenborough often takes a quirky and unexpected look at aspects of the plant kingdom. He thinks that plants have often used us as much for their ends as we have them for ours. I especially enjoyed the "wheat's-eye-view" of its domestication — enlisting humans to enable it to defeat rival plants and spread over huge areas of the globe! Although Attenborough states that scientific sources would be out-of-place in this book, it would have been useful to have a list of further reading for anyone whose interest had been caught by a specific topic.

But these are minor quibbles. This is a book to be enjoyed. Like many others of my generation I suspect, I can attribute at least part of my own fascination for the natural world to some of Attenborough's early broadcasts. This present book, and its TV series, will serve to introduce a whole new generation to the wonder of plants. By making plants seem as charismatic as animals, Attenborough has done a great service to the science of botany.

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Plants of Kananaskis Country in the Rocky Mountains of Alberta

By Beryl Hallworth and C. C. Chinnappa. 1997. University of Calgary Press, c/o UBC Press, 6344 Memorial Road, Vancouver, British Columbia, V6T 1A2, XLIC +368 pp. illus. \$19.95 + \$5.00 shipping + 7% GST on total amount (outside Canada, prices are in U.S. dollars; shipping overseas \$9.00; cheques should be made payable to UBC Press).

"Kananaskis Country was created to preserve a beautiful area of the Rockies: the rugged western mountains with extensive glaciers; the Kananaskis, Elbow, Sheep and Highwood rivers with their many tributaries; the beautiful lakes; and the foothills scenery. The area is ecologically diverse, supporting

significant populations of wildlife and an extensive flora The plant life is equally diverse and features alpine species, grassland plants, marsh plants, and forest species as well as aquatic plants in the lakes and rivers." It covers an area of 4160 square kilometers lying adjacent to Banff National Park and the Alberta-British Columbia border on the west. This most interesting region attracts many thousands of visitors every year and a book such as *Plants of Kananaskis Country in the Rocky Mountains of Alberta* will be extremely valuable to them.

The introduction is followed by six well-drawn maps of the region which depict the roads, rivers,

day use and camp grounds, and many information centres. A few pages are then devoted to descriptions of the geology, climate, vegetation zones, and directions on how to use the book to identify a plant and plants of special interest. Sixteen pages of excellent colour photographs, mostly taken by C. C. Chinnappa, illustrate plant families found in Kananaskis Country together with some most interesting habitats from grasslands and wetland to the mountains.

The next 276 pages of this most interesting and useful book are devoted to easy-to-read and use keys, descriptions and notes for the families, genera, and over 400 species of the more obvious plants found in the region and these are accompanied by over 1500 very fine line drawings. Appendix 1

describes other botanical investigations related to the region; Appendix 2 provides an alphabetical list of the families, genera, and species together with common names; a Glossary provides explanations of the technical terms found in the text together with a series of well-labelled drawings depicting shapes and parts of various plant species. A list of references and an index of the scientific and common names found in the text complete this most useful work.

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ENVIRONMENT

Passing the Buck: Federalism and Canadian Environmental Policy

By Kathryn Harrison. 1996. University of British Columbia Press, Vancouver. 238 pp. \$70.

Government is often looked upon by society as a protector of the public resources. This may be construed by many as a call for leadership (a guiding force) in a number of areas including environmental policy. Kathryn Harrison provides us with a book dealing with the issue of the federal role in developing environmental protection policy. The book is based on a study that uses "the case of environmental protection to explore the phenomenon of policy inaction within Canadian federalism." The author used a variety of documentary sources supplemented with seventy-six unstructured interviews with individuals.

The material takes the reader first from the theoretical concepts involved and then to the historical development of environmental policy with appropriate analysis. The final chapter provides a wrap-up of the material covered and a look to the future. Ms. Harrison has provided the reader with well-structured chapters with concise conclusions. Notes, bibliography and index are provided to help the reader move through the text. Acronym definitions are obtained within the text and in the index if they were

forgotten. The book is written in technical manner but quite readable.

The text unveils to the reader a federal process which, when dealing with environmental protection policy, is at best reactionary. The historical information suggests a system created by the political powers that is more concerned with image and than substance. One gleam of hope provided by the author is a suggestion that as environmental problems have a larger impact on individual lives the pressure from society will increase. The increased pressure should result in greater government involvement according to past governmental performance.

For individuals working with environmental protection policy this book should provide a greater understanding of the process. With this understanding will come increased awareness from where leadership for this issue comes. Kathryn Harrison has provided an interesting look at the workings of federal government policy setting.

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A Nature Guide to Ontario

Edited by W. Wake. 1997. University of Toronto Press, Toronto. xxxiii + 469 pp., illus. Cloth \$65; paper \$19.95.

There has been a real need for an up-dated version of the classic *A naturalist's guide to Ontario* for many years now. The Federation of Ontario Naturalists undertook to satisfy this need by compiling contemporary site information from a variety of individual naturalists, from published literature, and from unpublished government reports. This site information was arranged into regional units, packaged with introductory and supporting material and published as *A nature guide to Ontario*. And does it work? Well, sort of.

The *Guide* does a masterful job of compiling existing information on a large number of natural areas. It's hard to imagine a provincial government natural areas report produced in the last 20 years from which information is not extracted. The *Guide* has a quite satisfactory introductory treatment that considers the landscape and ecological character of the province as a whole and provides suggestions and directions for exploring Ontario's biodiversity. The "Reference Materials" section at the back is first rate, providing a very useful listing of published reference materials, guides, maps and such. This, however, is accompanied by a less useful glossary (why bother?) and a poor "Useful Addresses" (are the useful addresses in Ontario really only those of government agencies and a handful of NGOs?). There is also the predictable central section of "pretty nature pictures" ... yes, even the proverbial brown-eyed deer standing in a sun-dappled, forest clearing. The large expense of such spreads is typically rationalized as the necessary cost of attracting additional readers. Has anyone ever tested this, I wonder?

Upon opening the *Guide*, one is immediately struck by its most serious and almost fatal flaw ... no site maps. It is unbelievable and entirely unacceptable that contemporary readers/users are expected to find obscure and out-of-the-way places with only written directions. Try figuring out, for example, where in West Wawanosh Township the Saratoga Swamp site is and how one gets there *via* West Wawanosh Concession Road 4-5 (page 179). Even assuming one can follow the often convoluted instructions, what happens when road names or numbers change? You get lost. Maps are essential, period. That is why these things are called *guides*.

The site treatments make rather "flat", uninspiring reading. Most have the feel of summaries extracted from primary sources by someone with limited or no familiarity with the site in question. The "Further Information" reference offered with some site treatments is frequently of little use; e.g., the many

dozens of references that simply say "MNR" (Ontario Ministry of Natural Resources). Clarity is further hampered by the absence of any scientific names in the main text. The usual reason given for this lamentable practice is as a simplification for novices. How many novices, however, will be induced to search out the spectacular Buttermilk Falls site (page 311) by the "simplified" news that Aquatic Mustard, American Littorella, and Lesser Waterwort are the stars of that place? Such obscure and frequently changeable common names would have to be looked up in the master list at the end of the book anyway, and many readers just won't bother. Without a lot more information, only those with sufficient knowledge to recognize what *Subularia aquatica*, *Littorella americana*, and *Elatine minima* represent will appreciate this (one of the richest aquatic associations in southern Ontario, by the way) to be a dynamite site.

There is a strong Toronto area bias to *A Nature Guide to Ontario*. That is perhaps an understandable marketing tack — this is where most of the people are, after all. Still, it's annoying to see a supposedly province-wide guide treating Thunder Bay District which is the size of many European countries with barely more coverage than that of tiny Peel Regional Municipality on the outskirts of Toronto. This regional bias is further underscored by the silly Letterman-esque listing of "The Top Ten" natural areas as determined by "some of the province's most travelled and seasoned naturalists" (page xxvi). Seven of their selections are found within a few hours drive of Toronto in the most populated southern $\pm 10\%$ of the province. The list does not even include what is undoubtedly Ontario's most famous natural area, Algonquin Provincial Park. Mercifully, the "well-seasoned naturalists" who developed the list are not identified.

All in all, then, if you are interested in visiting natural areas in this province should you bother to acquire *A Nature Guide to Ontario*? Sure, since this compendium of sites is the most comprehensive presently available. If you do, however, be prepared to undertake the additional digging for maps and information that the *Guide* should have already done for you. On the other hand, perhaps you could find a list of local natural history clubs (no ... that's not in the *Guide* either) and hook up directly with a naturalist who knows the local situation. At least you won't get lost!

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The Web of Life: A New Scientific Understanding of Living Systems

By Fritjof Capra. 1996. Anchor Books (Doubleday Canada, Toronto). xix + 347 pp., illus. \$32.95.

What is life? Like a Zen koan, this deceptively simple question has stirred generations of philosophers and biologists with its limitless implications. Fritjof Capra, a theoretical physicist by training, and the author of *The Tao of Physics*, attempts to integrate recent breakthroughs in such diverse fields as chemistry, mathematics, and evolutionary theory into a coherent view of the essential nature of life.

He successfully argues that science is undergoing a paradigm shift away from mechanistic, structural thinking towards an emphasis on pattern and process. Traditionally science has focussed on structure: atom, molecule, cell, organism. Such reductionist approaches risk failing to perceive emergent properties of interconnected structures. As a simple example, one could have profound knowledge about the physical properties of hydrogen and oxygen and yet be unable to predict the elegant complexity of a snowflake.

Capra weaves together his thesis with strands of cybernetics, threads of systems thinking, filigrees of non-equilibrium chemistry, and patches of fractals and chaos theory. Because of this the reader is often left desiring to know more about those things encountered for the first time while feeling other topics received too much attention. This is always the risk in any multi-disciplinary book, but Capra provides extensive endnotes and suggested further readings for those that wish to explore certain avenues.

To be fully understood, Capra argues, life must be viewed as the integration of structure, pattern and process. The enigma of life is that it is both an open (structurally) and closed (organizationally) system. The delightful analogy Capra uses is of a vortex of water spiralling down a bathtub drain: the system is both open (water flows through the vortex) and closed (the nature of the vortex remains). Such forms — dissipative structures — are at the heart of Ilya

Prigogine's research which ultimately earned him the Nobel Prize. Dissipative structures can not only maintain themselves in a stable state far from equilibrium they can also evolve into new structures of increasing complexity. The evolution of new species can be viewed as a similar process. Competition is important, but cooperation and mutualistic responses may be even more vital to evolution. For example, the diversity of flowering plants and insects are tightly bound together.

But what of life itself? The origin of life has always been a challenge to biologists. That life could form randomly out of a "molecular soup" given sufficient time and the right conditions, has been widely accepted. Now this mechanistic theory has been challenged by Nobel laureate Manfred Eigen. Studies of catalytic reactions involving enzymes far from equilibrium found that they tended to interlock to form closed loops, with enzymes produced in one cycle acting as catalysts in subsequent cycles. These "hypercycles" are stable, capable of self-replication and even of correcting replication errors. Self-organization appears to be a fundamental property of biochemical and living systems; the importance of randomness has been greatly exaggerated.

It is impossible to do justice to even a handful of the challenging ideas Capra brings together. It is remarkable that such sophisticated concepts and theories are put forth with such clarity and accessibility. Ironically it has taken a physicist to explain biology in a truly biological manner, but Capra has indeed fulfilled the promise of his subtitle: a new scientific understanding of living systems. *The Web of Life* is rewarding and perhaps even essential reading for anyone interested in the inherent mystery of life.

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Life in 2030: Exploring a Sustainable Future for Canada

J. B. Robinson, D. Biggs, G. Francis, R. Legge, S. Lerner, D. S. Slocombe, and C. Van Bers. 1996. University of British Columbia Press, Vancouver. 168 pp. \$25.95.

Almost daily we, as Canadians, are reminded of the exploding world population, impending food scarcity and environmental degradation. We are rapidly approaching a point in our history when preserving our environmental and natural heritage will no longer be an option. *Life in 2030* describes a five-year modeling project to determine some of the effects of possible decisions. The book is not meant to answer questions but to provoke them.

J. R. Robinson et al. provide the reader with a technical description of how the model was developed and tested. A main feature of the model would appear to be what the authors have termed as back-casting. A process of determining in what direction society would like to see their future develop and then determining how to achieve the desired objective. The societal objective used is the Conserver Society, a concept developed between 1975 and 1979. This objective alone will generate a great deal of discussion in some circles. The other issue, which is mentioned but not discussed, is the ecological

footprint such a Canadian society would leave on the rest of the world.

As mentioned, the authors provide a technical review of the model developed and its projected society. Review of the material after the first reading, I believe and the authors suggest, is needed to fully comprehend the societal changes developed in the model. The reader is provided with chapter conclusions, reference lists, and index to help review material. The information provided does accommodate further reading, refreshing ideas and quick retrieval to aid the process of comprehension.

Life in 2030, as suggested, is not a book for light reading. This is a book which requires some understanding of the issues involved and society's potential responses. An understanding of the modeling process would not hurt either. The book's stated aim to provoke discussion of the issues is accomplished but the discussion will come from a technically literate group not from the general reader.

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MISCELLANEOUS

The Bird Collectors

By Barbara and Richard Mearns. 1998. Academic Press, San Diego. 472+xviii pp., illus. U.S. \$29.95.

This interesting volume gives a detailed account of the diversity of individuals who amassed bird collections around the world, with a particular emphasis on the British. The Mearns begin by pointing out the massive extent of bird killing in general, the causes of extinctions, and the tiny impact of collecting. The objectives and methods of ornithology are then examined in terms of field work, curation, taxonomy, publications, applications, and the associated human motivations. The bulk of the chapters are an historical review of leading figures, expeditions, and institutions, with due emphasis on the nineteenth century. The rich panoply of topics includes taxidermy, endemic and extinct species, and the roles of governments and various professions, including the colonial military, medics, and missionaries. The impacts of bird art, of professional collectors, and of expeditions to remote areas are well considered. Contributions by women and the growth of bird conservation are also carefully documented. The especially welcome final chapter deals with the importance of new and old collections: their multiple uses, and the reasons for continued collecting and for caution in doing this. A consideration of animal rights appropriately completes

the circle to the ethics of collecting correctly raised in the Preface.

The intriguing and up-close biographical portraits are supported by quotations, droll anecdotes, and tales of commitment, joy, and suffering, all of which heighten the human element. There is much social history and travel lore in the narrative with little attention to scientific issues per se. There are numerous black-and-white figures, some long summary tables, references, and indices. In the appendix listing the world's 69 major collections, Canada is found in spots 13 and 18, and Canadian content includes the material on J. H. Fleming and the Hudson's Bay Company. At several points in the book a deeper discussion would have been warranted on such issues as the impact of Darwinism, the reappearance of rare species, the strategic development of collections, and their contribution to specific scientific disciplines. Overall this book provides an excellent single source on the amazing array of persons who built our avian collections, and should be read by anyone with an interest in birds or the history of science.

PATRICK COLGAN

Dobbin House, 209 John Street P.O. Box 1395, Niagara-on-the-Lake, Ontario L0S 1J0, Canada.

NEW TITLES

***Amphibians and reptiles of the Great Lakes Region.** 1998. By J. Harding. University Michigan Press, Ann Arbor. 378 pp., illus.

Birds of China. 1997. By C. Cizu, Z. Xiang, and P. Bingzhang. China Forestry Publishing (distributed by University British Columbia Press, Vancouver). 200 pp., illus. \$59.95.

***The butterflies of Canada.** 1998. By R. A. Layberry, P. W. Hall, and J. D. Lafontaine. University of Toronto Press, Toronto. 280 pp., illus. Cloth \$100; paper \$29.95.

Cats of Africa. 1998. By P. Bosman. Smithsonian Institution Press, Washington. 152 pp., illus. U.S. \$45.

Distribution of mammalian species in China. 1997. By Z. Yongzu. China Forestry Publishing (distributed by University British Columbia Press, Vancouver). 217 pp., illus. \$195.

†**Endemic bird areas of the world: priorities for biodiversity conservation.** 1998. By A. Stattersfield, M. Crosby, A. Long, and D. Wege. Smithsonian Institution Press, Washington. 846 pp., illus. U.S. \$60.

†**A field guide to birds of the Gambia and Senegal.** 1998. By C. Barlow and T. Wachter. Yale University Press, New Haven. 400 pp., illus. U.S. \$40.

A field guide to spiders and scorpions of Texas. 1997. By J. A. Jackman. Gulf, Houston. xiv + 201 pp., illus. U.S. \$18.95.

Foraging for survival: yearling baboons in Africa. 1998. By S. A. Altmann. University Chicago Press, Chicago. c536 pp., illus. U.S. \$70.

Forest cats of North America: cougars, bobcats, and lynx. 1997. By J. Kobalenko. Firefly Books, Buffalo. 128 pp., illus. U.S. \$19.95.

***A guide to identification and natural history of sparrows of United States and Canada.** 1996. By J. D. Rising and D. D. Beadle. Academic Press, San Diego. xii + 365 pp., illus. U.S. \$19.95.

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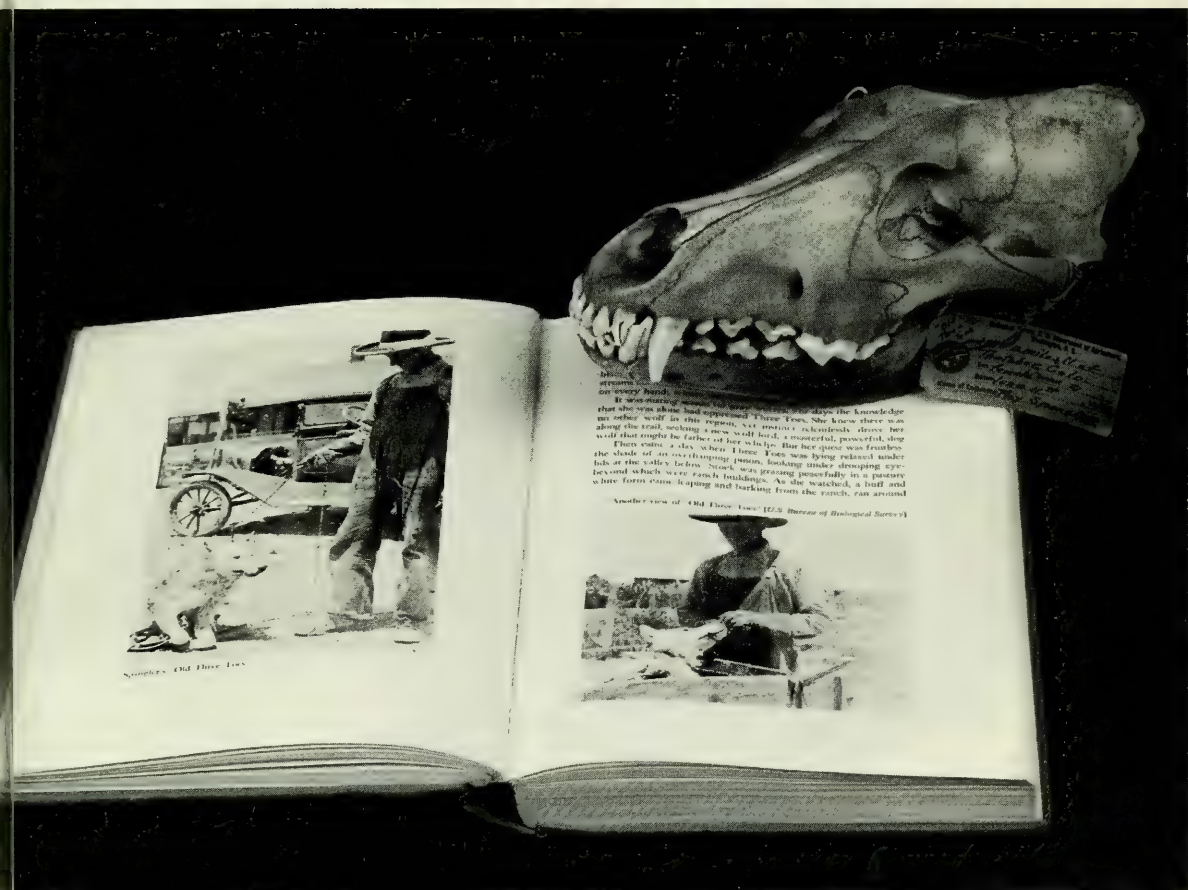
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Cover: The skull and photographs of a notorious Gray Wolf, *Canis lupus*, Old Three Toes of the Apishapa, captured in 1923. The wolf mated with a ranch dog and raised a litter of hybrid pups. Ranchers claimed the wolf and her pack killed cattle and sheep worth thousands of dollars. Photographs of Three Toes are shown as printed on pages 76 and 77 of the book *Last of the Loners* by Stanley P. Young, 1970, The Macmillan Company, New York, New York, 315 pages. The photographs are the property of the Biological Survey Archives, National Museum of Natural History, United States Geological Survey, Washington, D. C. and are reproduced here by their permission. See review of the accounts of 59 famous Wolves by Philip S. Gipson and Warren B. Ballard on pages 724-739.

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Observations of the Long-toed Salamander, *Ambystoma macrodactylum*, in Waterton Lakes National Park, Alberta

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Fukumoto, Julie, and Stephen Herrero. 1998. Observations of the Long-toed Salamander, *Ambystoma macrodactylum*, in Waterton Lakes National Park, Alberta. Canadian Field-Naturalist 112(4): 579–585.

The ecology of the Long-Toed Salamander (*Ambystoma macrodactylum*) was studied in Waterton Lakes National Park, Alberta, and evidence of its presence was obtained at nine of thirteen study sites. Populations occurred throughout the park at elevations from 1280 to 1930 metres in habitat that varied from aspen parkland to subalpine forest. Salamander breeding activity occurred from early April to late June, depending on location. Development of larvae in lakes or ponds is usually completed in one season (i.e., during one summer); however, two-season development was indicated at Summit Lake (elevation 1930 m). Mark-recapture data were obtained at Linnet Lake by conducting night searches and utilizing drift fencing and pitfall traps. A Schumacher-Eschmeyer estimate of between 3274 and 4690 breeding adults (95% confidence interval) was obtained for the population. Human impacts included roadway mortality and alteration of habitat due to local contamination and/or global effects. The total count of salamander roadway mortalities near Linnet Lake in 1994 was equal to 1.4 to 2.0% of the estimated population of breeding adults. Roadway mortality also may have contributed to the unusual female biased 3:1 (464 females:155 males) sex ratio obtained for this population. Measurements of pH taken at several aquatic breeding sites indicated a decrease in pH of 1 to 2 1/2 units had occurred in the last twenty-five years; the change may pose a potential threat to salamanders. Acid precipitation may be the source of this change.

Key Words: Long-Toed Salamander, *Ambystoma macrodactylum*, ecology, conservation, breeding, development, roadway mortalities, mark-recapture, population, Alberta.⁹

The Long-Toed Salamander, *Ambystoma macrodactylum*, is found in western North America (Ferguson 1961; Stebbins 1985). In Alberta, the slopes of the Rocky Mountains are generally considered to delineate the eastern fringe of the Long-Toed Salamander's range (Cook 1984; Russell and Bauer 1993). However, the species has also been reported to the east in the Peace River region of Alberta (Walsh 1998). The study reported here was carried out to examine its ecology in Waterton Lakes National Park (WLNP) with emphasis on management for its protection in the park (Fukumoto 1995).

The Long-Toed Salamander is terrestrial outside of the breeding period and primarily nocturnal. Activity above ground is restricted to avoid desiccation. Its life history is typical of the smaller ambystomatids (Hairston 1987). In temperate mountain regions, breeding migrations occur in spring when terrestrial adults move to ponds to breed and lay eggs; eggs then hatch into larvae which develop in the aquatic habitat, usually over one summer, before undergoing final metamorphosis into the terrestrial juvenile form (Ferguson 1961; Anderson 1967; Russell and Bauer 1993).

WLNP is located in the southwest corner of Alberta, bordering the east side of the Continental

Divide, and is 526 km² in area. Despite its small size, a major transition from mountain to prairie life zones occurs within its boundaries, thus enhancing biological diversity. WLNP and Montana's Glacier National Park together form the Waterton-Glacier International Peace Park. The Waterton area also is recognized by UNESCO as a world biosphere reserve (Pringle 1986). Most human activity in WLNP occurs in late spring through summer when businesses in the townsites are open and cottagers visit. Although the study area lies within the protected confines of a national park, many changes to it have resulted from human activity, and impacts upon Long-Toed Salamanders and other wildlife have occurred.

It was not realized until 1992 that at least one relatively large population of Long-Toed Salamanders existed in WLNP (Morrison 1992). At that time, movement of a large number of adult salamanders to a breeding site, Linnet Lake, was blocked by a 465 m long curb resulting from the construction of a sidewalk along the main parkway (road). The sidewalk had been constructed two years earlier in 1990. Although the sidewalk problem was mitigated in fall 1993 by grading the curb, the lack of basic information

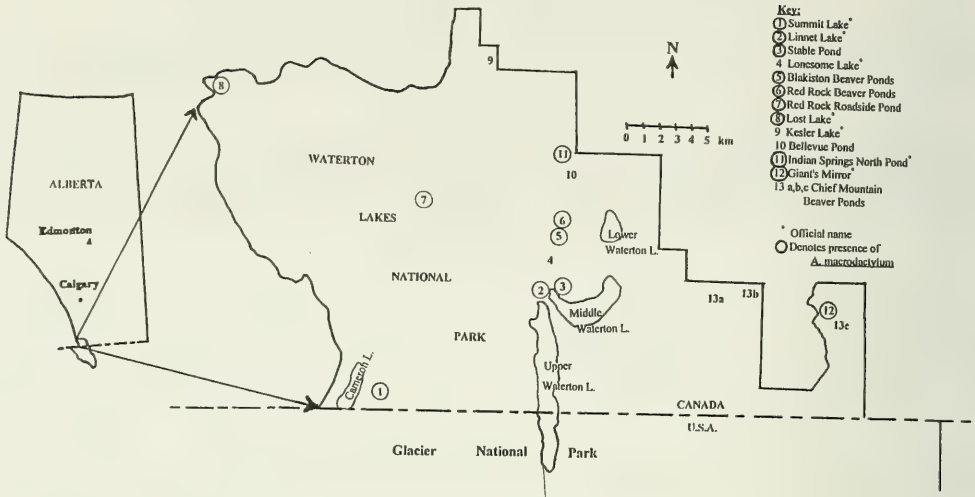


FIGURE 1. Waterton Lakes National Park study sites.

about the species had become apparent. This study was then initiated.

Methods and Materials

Thirteen sites (lakes and ponds) within the boundaries of WLNP were selected for the study (Figure 1). The sites were examined to help establish the distribution of *A. macrodactylum* in the park. A mark-recapture study was conducted at Linnet Lake (49°04' N, 113°54' W), an oblong 3.5 hectare lake situated at 1280 metres elevation, near the Waterton townsite. Mount Crandell rises to the west, and the only road into and out of the townsite (from outside the park) runs parallel to the west shore of the lake (Figure 2). The terrestrial habitat available to the salamander population in other directions around Linnet Lake is restricted to the slopes of the hill that separates the lake from the large Middle and Upper Waterton Lakes. The slopes surrounding the lake are covered with grass, shrubs, and montane forest.

In addition to this primary study site, other temporary and permanent water bodies within WLNP were examined. Most of the ponds and lakes were less than 3 hectares in area, and the largest was less than 15 hectares. They had mud substrates, and varying amounts and types of aquatic vegetation. Elevations of the study sites ranged from 1280 to 1930 metres. Immediate surroundings were comprised of grass, aspen, or conifer cover. Most of the study sites (including Linnet Lake) were stocked with trout at one time. Linnet Lake has also been exposed to chemical disturbances in the past, including treatment with rotenone (a biocide agent) in fall 1950 and fall 1966 to eliminate undesirable fish species, and treatment with 2-4-D to get rid of weeds in spring 1960 and June 1967. Laundry effluent from the near-

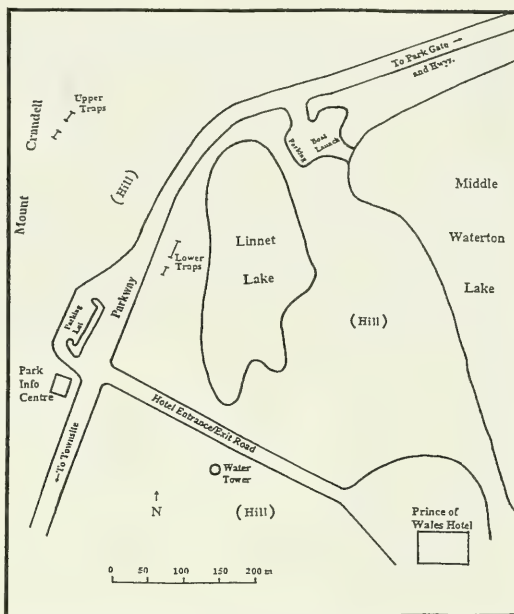
by Prince of Wales Hotel also was disposed of in the lake until 1977 (it was not determined when this practice was started).

The pH was measured to the nearest 0.5 unit using chemical indicator sticks (BDH Chemicals Canada Limited) on a monthly basis during the 1994 field season. Daily precipitation and temperature data for the Linnet Lake vicinity were obtained from the Waterton Parks Service.

Field work was conducted over the spring and summer of 1993 and of 1994. Searches were conducted at study sites for signs of Long-Toed Salamanders. Observation of *Ambystoma macrodactylum* eggs, larvae, juveniles, and/or adults indicated the species' presence. Two methods were used to capture salamanders at Linnet Lake: (1) night searches, and (2) drift fencing and pitfall traps.

Night searches for salamanders were conducted by jacklight along the 465 metre section of parkway running parallel to the west shore of Linnet Lake. Much of the 1993 spring breeding activity was missed due to late initiation of the study; however, salamander activity was monitored from 12 April to 15 September in 1994. Salamanders were retained in buckets or large plastic containers placed in designated sections of the parkway, until they could be marked (toe clipped), measured, and their sex determined (method details in Fukumoto 1995). A small volume of dechlorinated water was added to the containers in which salamanders were retained in order to keep the salamanders moist. Salamanders moving in opposite directions were placed in separate containers so that they could be returned heading in the appropriate direction. The majority of captures were made during the breeding period, when, in most cases, downslope (eastward) or upslope (westward)

The assumption of equal catchability was probably the most difficult to satisfy. A time lapse occurred between initial capture of a salamander and its



recapture, due to the time spent moving to and from the lake and in breeding activity, and individual salamanders would not have been equally catchable on a nightly sampling basis. However, each should have had an equal chance of capture over the entire breeding period. In order to account for this time lapse, the nightly sampling events were grouped into four longer sampling periods, based on trends in salamander movements (i.e., primarily downslope, some upslope movement, more upslope movement, and movement primarily upslope). The Schumacher-Eschmeyer estimator was then applied to the grouped data.

Observations at the study sites indicated that salamander breeding migration and activity in lakes and ponds coincided closely with spring thaw, which occurred in early April to late June depending on elevation. Linnet Lake (elevation 1280 m) normally thaws by early April. Breeding activity at the lake in 1994 lasted from early April through the end of May, although peak movements across the parkway occurred between 19 April to 15 May (Figure 3: Days 8–34). Most salamander movement at this site

was observed in the first few hours after dusk. Minimum daily air temperatures at Linnet Lake remained above 0°C on 41 of 50 days during the period from 12 April to 31 May 1994. Below-freezing temperatures occurred during periods of late snowfall, during which salamanders were not observed. More salamanders moved when it was raining, or when the ground was moist from earlier rain or from snowmelt. Salamander captures coincided with surface moisture on 25 of 37 nights during which captures were made. Peaks in movement appeared to occur after short dry spells, on nights when it was raining or had rained earlier in the day sufficiently to moisten the ground.

In 1994, twenty-seven recaptures (20 females and 7 males) were made along the parkway near Linnet Lake in which the salamanders were initially caught heading downslope towards Linnet Lake and then recaptured heading upslope. Among the females, a mean time of 19 days ($SD = 6$) elapsed between initial capture and recapture, with a range of 10 to 28 days. The mean time between captures for males was 27 days ($SD = 4$), with a range of 22 to 35 days. Some of this time was spent in moving from the parkway (where captures were made) to the lake and vice versa, a distance of approximately 25 to 100 m.

At most study sites in WLNP, 4 to 5 1/2 months were available for larval development. Less time was available at temporary ponds (as little as 2 1/2 months), and at higher elevation sites (3 to 3 1/2 months). Larval development at most sites in WLNP occurs in one season (i.e., over one summer). However, two distinct sizes of larvae were observed in Summit Lake (elevation 1930 m) in 1994. On 23 July 1994, two Long-Toed Salamander larvae were captured in this lake. The larvae were 65 mm in total length, and were already in advanced stages of development. Dorsal stripes were forming, external gills were shortened, and fore and hind limbs were in an advanced stage of development, indicating that the larvae were almost ready to undergo metamorphosis. On 12 August 1994, two small salamander larvae were observed in the same lake. The larvae must have hatched that spring because they were only about 25 to 32 mm long with some early fore and hind limb development.

A total of 619 individual adults were captured near Linnet Lake in 1994 with a recapture rate of 5.8% (36 of 619 adults). The vast majority of captures (597 salamanders) was made prior to 1 June 1994. Five of 49 adults marked in 1993 also were recaptured in 1994. The salamanders appeared to be in good condition and toe clipping did not appear to have had negative effects. Clips were also easily identifiable.

Based on the 1994 data, a Schumacher-Eschmeyer estimate of 3856 salamanders (95% confidence limits of 3274 to 4690 salamanders) was obtained for

the breeding population at Linnet Lake. Captures made in pitfall traps showed that some adults and newly transformed juveniles moved at least 200 m up the slope of Mount Crandell, to the west of Linnet Lake. Adults at Linnet Lake averaged 130.6 mm in total length ($SD = 7.6$, $n = 547$) and weighed an average of 6.1 g ($SD = 1.2$, $n = 542$). An unusual female:male ratio of 3:1 (464 females : 155 males) also was obtained from the 1994 Linnet Lake data.

Nightly counts of mortalities on the parkway by Linnet Lake in 1994 were not high, but the combined count of 67 roadkills during the period from 12 April to 15 September was equivalent to 1.4 to 2.0% of the estimated population size of breeding adults. Other amphibian and reptile species were at risk of roadway mortality; six Western Toad (*Bufo boreas*) and three Garter Snake (*Thamnophis elegans* and *T. sirtalis*) mortalities also were observed on the parkway.

Measurements of pH at several of the study sites, including Linnet Lake, showed a change of 1 to 2 1/2 units in comparison with readings taken in the 1970s (Anderson and Donald 1976). Available data indicated a change in water composition from alkaline to acidic (i.e., approximate change of pH 8 to pH 6). The pH at Linnet Lake changed from 8.3 to 6.0.

Discussion

Salamander populations in WLNP are distributed throughout a range of elevations and habitats. The utilization of diverse habitats by *A. macrodactylum* is not unusual; populations have been found in habitat varying from semi-desert sagebrush to alpine meadows (Ferguson 1961) and from coastal sea-level to high mountain elevations (Kezer and Farner 1955; Anderson 1967). The presence of several disjunct populations in Waterton corresponds to the dispersion of populations found in other mountain regions of Alberta (Salt 1979; Russell and Bauer 1993). Although its precise migration route into the Waterton region is unknown, *A. macrodactylum* has evidently been able to establish populations at various locations since the last major glacial retreat in the region 10 000 years ago. Present study site populations are probably distinct from each other, because of the geographic division between sites and the tendency of many amphibian species, including those of *Ambystoma*, to exhibit site fidelity and homing ability (Whitford and Vinegar 1966; Stenhouse 1985; Blaustein et al. 1994).

The timing and duration of breeding activity for *A. macrodactylum* is dependent on climate and varies over the species' range (Ferguson 1961). The breeding activity of *A. macrodactylum* in WLNP follows the early spring breeding pattern described for temperate mountain climates, whereby an overwintering period is followed by a spring migration to breeding ponds, often as soon as ice starts to melt (Anderson

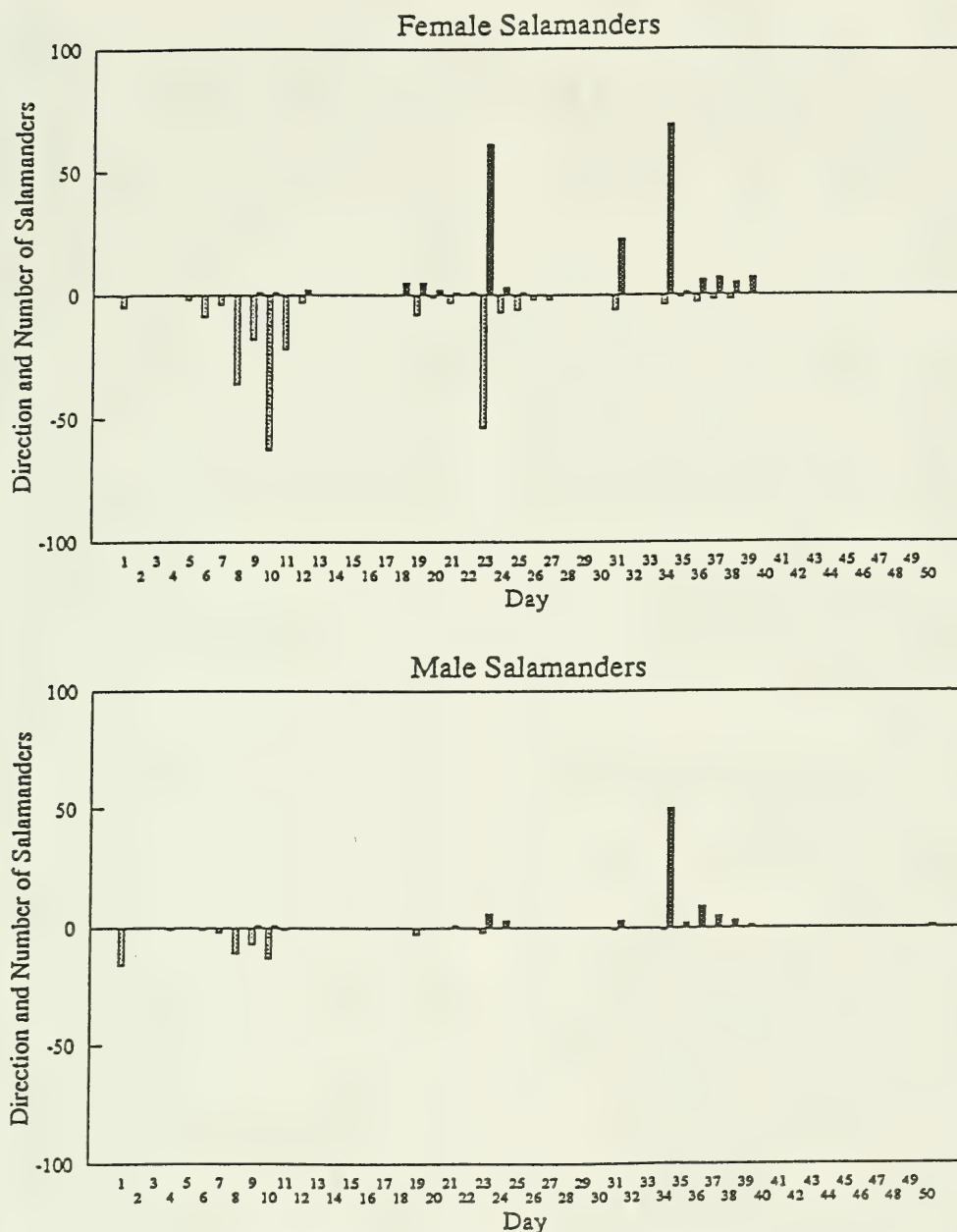


FIGURE 3. Female (top) and male (bottom) salamander movement across parkway at Linnet Lake. On each histogram the movement downslope towards Linnet Lake is shown below the line, and movement upslope away from the lake is shown above the line.

1967). At Linnet Lake, surface moisture was a primary environmental condition influencing breeding migrations. Breeding activities went on for about two months, with individuals generally spending less than four weeks near and in the lake. Early completion of breeding helps to ensure that larvae have sufficient time for development and allows adults more time to

forage and return to overwintering sites (i.e., allows repletion of body energy stores prior to winter).

Salamander larval development in WLNP appears to follow patterns similar to those identified for *A. macrodactylum* in other studies (Kezer and Farner 1955; Anderson 1967). In the Cascade Mountains of Oregon, Kezer and Farner (1955) found that larvae

developed in one season at elevations below 1680 m, and in two seasons at elevations over 1830 m in permanent water bodies. The observations of two distinct sizes of salamander larvae in Summit Lake provide evidence that larval development may take two summers at higher elevations in the park. It is highly improbable that the larger larvae could have developed in the six-week period from ice thaw (when eggs would have been laid) until the time of observation. It is uncertain whether the smaller larvae observed in the lake would have completed development in one season. Given the weather conditions in 1994, which would have resulted in warmer water temperatures and a longer period for development, one season development may have been possible at this locality.

A large estimate was obtained for the Linnet Lake salamander population size. This estimate was for the breeding population, and the size of the entire terrestrial population, comprised of both juveniles and adults, would be greater. Large estimates also have been obtained for *A. macrodactylum* populations on the front range of the Rockies near Canmore, Alberta (Powell et al. 1997). It appears that even on the edge of the species' range, large populations can be sustained provided suitable habitat is available.

The roadway mortalities observed along the parkway near Linnet Lake represent a potentially serious threat to the salamander population. Large numbers of salamanders may cross the parkway during spring breeding migrations and losses could be substantial. The effect on the population may be especially significant because reproductive adults are the predominant victims. Amphibian mortality on roadways is a problem in many European countries; it is estimated that over 20% of breeding adult amphibians are killed by vehicles each spring, or as much as 40% in some years (Langston 1989). At Linnet Lake, the cumulative count of salamander roadkills in 1994 may not seem high, but the number of roadkills and effects on the population over many years could be significant. The count obtained in 1994 is almost certainly an underestimate; more salamanders likely would have been killed if they had not been captured and removed from the parkway during the night searches. Mortality on the parkway will vary depending on traffic volume and timing, concomitant with the rate and timing of salamander migrations.

The 3:1 sex ratio obtained at Linnet Lake, indicating a predominance of females, is contrary to other findings for most ambystomatids. Usually approximately equal numbers of males and females, or a predominance of males, have been reported in ambystomatid breeding aggregations (Husting 1965; Whitford and Vinegar 1966; Beneski et al. 1986; Pechmann et al. 1991). Greater numbers of females

are commonly observed in populations of the *A. jeffersonianum* complex where all-female polyploids are present with normal diploids (Uzell 1964; Lowcock and Murphy 1991; Rye et al. 1997; Bogart and Klemens 1997). Ploidy was not determined for the Linnet Lake population. A higher mortality rate among males could be a factor, with disproportionate numbers of males roadkilled along the parkway contributing to the unusual sex ratio. Husting (1965) found in *A. maculatum* that a slightly higher proportion of male salamanders bred annually compared with females. If males in the Linnet Lake population are more likely to breed annually, they would be at increased risk of being run over by vehicles on the parkway, as well as being exposed to a greater risk of predation. Over an extended period of time, a sex ratio skewed in favor of females might be maintained by such differential mortality.

Salamanders at Linnet Lake apparently have survived many chemical and biological changes in their aquatic habitat over time, but despite the salamanders' endurance, environmental changes must be considered as potential threats. The pH measurements obtained for several study sites indicate that acidification of their aquatic habitats has occurred. Such shifts in pH can have detrimental effects on amphibians as well as other aquatic organisms (Pough and Wilson 1977; Freda 1986; Freda and Dunson 1986) in the long term. Because several sites seem to have undergone this acidification, the source may be a global problem such as acid precipitation.

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Dispersal and Mortality of Juvenile American Black Ducks, *Anas rubripes*, on Wetlands under Different Management Strategies

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Understanding the factors which influence the survival of juvenile American Black Ducks is critical to maintaining or enhancing rates of recruitment, a factor important in meeting the stated population goals of the North American Waterfowl Management Plan. To contribute to that knowledge base, and to compare survival on wetlands under different management strategies, this five-year study of radio-marked HY juvenile Black Ducks was initiated in the Maritime Provinces of Atlantic Canada. Two hundred and forty-six radio-marked juvenile American Black Ducks (*Anas rubripes*) were monitored on three study sites in New Brunswick and Nova Scotia during the summer/fall periods from 1987 through 1991. The three sites represented wetlands under the following management strategies: unmanaged forested (UF); managed-hunted (MH); and managed-sanctuary (MS). Post-fledging dispersal (≥ 10 km from natal marsh) was greatest (26%) on UF and least (1%) on MS. Mortality from hunting on or near natal wetlands was only slightly greater on MH (56%) than on MS (48%). One-half of the mortality from hunting on juveniles produced on UF occurred on nearby (10-25 km) managed wetlands used for fall staging. Most radio-marked Black Ducks migrated south by early December, and mortality from hunting continued through December on wintering areas in southern Nova Scotia and northeastern United States. Total documented mortality on juveniles from hunting for MH, MS and UF was 60%, 57% and 22%, respectively. Managed wetlands on northern Black Duck breeding habitat may discourage post-fledging dispersal and contribute to high losses of HY juveniles to hunting early in the season. Size of protected wetlands and juxtaposition with other non-protected wetlands should be considered when developing sanctuaries or managed reserves to enhance Black Duck production and subsequent juvenile survival through the fall hunting season.

Key Words: Black Duck, *Anas rubripes*, juvenile, dispersal, mortality, radio-telemetry, New Brunswick, Nova Scotia.

An apparent sharp decline in the number of American Black Ducks, *Anas rubripes*, wintering along the Atlantic seaboard was first documented during aerial surveys in the mid- and late-1950s. Progressively lower numbers in subsequent years, at least into the early 1980s, prompted debate over the effectiveness of, or indeed the need for, more restrictive harvests. That debate continues. The protracted lack of consensus among researchers and managers on the role of hunting in survival and recruitment has resulted from the equivocal results of studies which have attempted to determine the extent that mortality from hunting may be additive or compensatory to natural mortality factors.

Although the North American Waterfowl Management Plan has the stated population goal of increasing the surveyed wintering population of Black Ducks from 300 000 to 385 000 [North American Waterfowl Management Plan, 1986. United States Fish and Wildlife Service and Environment Canada. 19 pages] most of the documented decline is now attributed to changes to breeding populations outside of Atlantic Canada. In Atlantic Canada both harvest statistics and breeding population surveys suggest that populations are relatively stable. However, in the mid-1980s the Canadian Wildlife Service, Environment Canada, and the Wildlife Agencies of the Maritime Provinces

expressed concern over the increasing hunting pressure on the network of managed wetlands which were being developed throughout the region in cooperation with Ducks Unlimited, Canada. Questions of whether these small and accessible managed wetlands served as sources or sinks for local and regional duck populations prompted this study by Canadian Wildlife Service of comparative rates of mortality on radio-marked juvenile Black Ducks produced on wetlands under different management strategies. This study also serves to address the concern by researchers and managers over rates of survival of juvenile Black Ducks from fledging to early fall migration, and contributes to the knowledge base required for a better understanding of the additive or compensatory nature of mortality from hunting.

The loss of juvenile American Black Ducks to hunting on or near natal wetlands has been identified as a potential factor contributing to depressed breeding populations and discouraging regional population recruitment and growth (Reed and Boyd 1974; Anderson and Burnham 1976; Parker 1991; Longcore et al. 1991). Although loss of waterfowl to hunting, especially juveniles, is generally considered to be partially compensated for by reduced mortality from other factors throughout the year (Anderson and Burnham 1976; Burnham and Anderson 1984; Burnham et al. 1984), the inconclusiveness of analy-

ses of band recoveries has left much uncertainty over the effectiveness of specific waterfowl management actions (Nichols et al. 1984; Krementz et al. 1987; Krementz et al. 1988; Nichols 1991; Smith and Reynolds 1992; Sedinger and Rexstad, 1994; Williams, et al. 1996). Blandin (1982), later supported by Boyd and Hyslop (1985), cautioned that population growth of Black Ducks might be suppressed by intensive hunting pressure on juveniles. Krementz et al. (1988) were unable to test adequately the relationship between hunting and total mortality for young Black Ducks due to deficiencies in banding and recovery data. In the absence of such data, and given concerns over declines in mid-winter counts of Black Ducks, they recommended a conservative approach to harvest regulations. An analysis of population and hunting data for Mallards (*Anas platyrhynchos*) across North America (Reynolds and Sauer 1991) documented an inverse correlation between population size and harvest rate. Conroy and Krementz (1990) provided a comprehensive review of evidence for and against mortality of Black Ducks from hunting being additive, compensatory or partially compensatory to other forms of mortality, and concluded that waterfowl managers have "inadequate scientific evidence" upon which "to determine whether hunting is an important factor contributing to Black Duck declines."

The recognized limitations and biases associated with regional and range-wide Black Duck banding programs emphasized the need for field research studies to supplement analyses of banding and band return data. This study, which describes the dispersal and mortality of radio-marked juvenile Black Ducks on three wetland sites in Atlantic Canada, each site representing a different strategy of habitat and regulatory management, was prompted in part by that need.

Study Area

The three study areas were (1) Shepody National Wildlife Area (NWA) (45°43'N, 64°43'W) in southern New Brunswick (managed wetlands and hunted), (2) Amherst Point Migratory Bird Sanctuary (45°45'N, 64°15'W) in northern Nova Scotia (managed wetlands and sanctuary), and (3) Lepreau (45°20'N, 66°35'W) in southwestern New Brunswick (unmanaged wetlands in forested habitat open to hunting).

Shepody NWA (described by Parker 1991) consists of 980 ha (wetland - 785 ha; upland - 195 ha) of diked impoundments on reclaimed Fundy soils and lies adjacent to tidal flats and saltwater *Spartina* marshes. Construction of dikes and water control structures was completed in 1978. At the time of this study (1987–1988) Shepody NWA represented one of the most productive and heavily hunted managed wetlands in Atlantic Canada. At the time, there were no specific restrictions for hunters other than

the general provincial and federal waterfowl regulations.

Wetlands in the Lepreau study area included freshwater lakes, streams and bogs within 630 km² of the upper portions of Lepreau and New River drainage basins. An earlier study on the impact of water acidity on the distribution and productivity of waterfowl at Lepreau (Parker et al. 1992) facilitated the logistics of this study. The Lepreau area is located at the northern terminus of the Appalachian Mountain System (Clayton et al. 1977) and most of the region lies between 200–300 m asl. Vegetation is typical of the Southern Upland Forest Section of the Acadian Forest Region (Rowe 1972). Common wetlands include shrub swamp, bog, open water, deep marsh and meadow (Canadian Wildlife Service, Atlantic Region, Sackville, New Brunswick; unpublished data following the wetland classification scheme developed by Martin et al. 1953). The climate is influenced by proximity to the Bay of Fundy, with cool summers, mild winters and frequent fog. Precipitation may reach 100–115 cm. (Putnam 1940). Due to high water acidity and suppressed populations of aquatic invertebrates, most natural wetlands in the Lepreau area do not represent preferred waterfowl habitat (Parker et al. 1992). Consequently, the Lepreau area of New Brunswick, similar to much of the interior freshwater habitat of the Maritime Provinces, is not habitat favoured by waterfowl hunters, approximately 25% of whom do most of their hunting on impoundments managed by Ducks Unlimited Canada. Only one-half of hunters surveyed in New Brunswick do most of their hunting on unmanaged freshwater wetlands [S. Bowes and M. Bateman. 1996. Results of the New Brunswick Migratory Game Bird Hunter Questionnaire, 1994. Unpublished Environment Canada and New Brunswick Fish and Wildlife Branch Report. 37 pages].

The Amherst Point Migratory Bird Sanctuary, established in 1947 on privately owned lands, is located in Nova Scotia near the New Brunswick border and includes 495 ha of upland and managed freshwater wetlands, much of which was former salt-marsh reclaimed by dikes almost 300 years ago. Three wetland management units, established in 1973–1977 (214 ha), and a natural lake (12.4 ha) represent waterfowl habitat in the sanctuary. The sanctuary, along with the 600 ha John Lusby Section (non-sanctuary status) on nearby saltmarsh, includes two impoundments of 8.0 ha (established in 1972) and 12.0 ha (established in 1974)) comprise the Chignecto NWA.

Waterfowl hunting is moderate to heavy on the streams, grainfields, impoundments and salt flats adjacent to the sanctuary. Hunting pressure is especially heavy during the first several weeks of the season, which, during the years of this study, opened on or about 8 October (over 80% of waterfowl hunters

surveyed in New Brunswick do most of their hunting in the first week of the season. [S. Bowes and M. Bateman. 1996. Results of the New Brunswick Migratory Game Bird Hunter Questionnaire, 1994. Unpublished Environment Canada and New Brunswick Fish and Wildlife Branch Report. 37 pages], although opening day bag checks, such as those at Shepody NWA, are not available. Reduced but sustained hunting pressure in the Nova Scotia - New Brunswick border area continues through November and early December. Much of the hunting is concentrated on the numerous managed wetland impoundments scattered throughout the border area.

Methods

Most juvenile Black Ducks were captured mid-July through mid-August by airboat at night (Parker 1991), were incapable of flight (locally produced), weighed ≥ 750 g and were aged as Class 11C or Class 111 (Gollop and Marshall 1954). The mean weights of radio-marked males and females were 955 g and 887 g, respectively (Table 1), and most had reached approximately 80% adult body weight. Radio harnesses were adjusted to allow for additional body growth. Subsequent examination of harnessed Black Ducks returned by hunters confirmed that those adjustments had been successful in avoiding restrictions of harnesses to maturing juveniles. Some were captured in August at bait-trapping stations and, although capable of flight, dried blood in the shafts of primary feathers indicated that they were on or near natal wetlands. At Lepreau and Shepody, several juveniles were captured by dogs.

Black Ducks were captured and marked at Shepody National Wildlife Area in 1987 ($n = 54$) and 1988 ($n = 42$), at Lepreau in 1989 ($n = 20$) and 1990 ($n = 41$), and at Amherst Point Sanctuary in 1990 ($n = 38$) and 1991 ($n = 51$). Each juvenile ($n = 246$) was marked with a standard USFWS leg band and fitted with a 28 g back-mounted radio

transmitter (Advanced Telemetry Systems, Inc. Isanti, Minnesota) attached with an adjustable harness (Dwyer 1972). Life expectancy of transmitters was 120 days with a transmission range over flat terrain of 1.5–2.0 km. Radio-marked juveniles were tracked with H-antenna, either mounted on a truck, the wing struts of a Cessna 172 aircraft (reception increased to approximately 15 km at 600 m altitude), or carried by hand. Transmitters with a steady signal over several successive days were investigated by foot or canoe. Where possible, radio-marked Black Ducks were monitored daily. At Lepreau, where access was difficult, radios were monitored several times/week. Cause of death for non-hunting mortalities was identified when possible.

Waterfowl hunting began at the Shepody and Lepreau study sites in southeastern New Brunswick on 1 October, a week earlier than the area around the Amherst Point Sanctuary of Nova Scotia (8 October). The season was delayed a week later (15–16 October) along the narrow coastal zone of southern New Brunswick (affecting Black Ducks marked at Lepreau only). A hunter bag check at Shepody on opening day in 1987 and 1988 facilitated collection of recovered transmitters. At Amherst and Lepreau most recovered transmitters were returned to CWS voluntarily (no hunter bag checks; address and phone number of CWS on back of transmitter). Some transmitters were located at hunter residences. Radio-marked ducks were checked regularly to determine crippling and unretrieved kill. Monitoring continued until all birds had migrated with the onset of cold weather, usually by late November - early December. Some transmitters were recovered in December by hunters on or near wintering areas in southern Nova Scotia, New Jersey, and Massachusetts.

I show comparative data on dispersal and fate of radio-marked juvenile Black Ducks produced on each of the three study sites. Preseason predation occurred

TABLE 1. Sample sizes and weights (g) of juvenile Black Ducks radio-marked at three study sites in Atlantic Canada, 1987–1991.

Study Site	Year	Males			Females		
		n	\bar{x} (g)	s	n	\bar{x} (g)	s
Shepody	1987	36	899.1	99.4	18	833.2	81.9
	1988	26	957.8	75.0	16	890.0	62.1
	Subtotal	62	924.1	93.8	34	860.7	77.4
Lepreau	1989	12	1016.6	85.5	8	907.5	104.3
	1990	21	947.6	104.2	20	848.7	101.7
	Subtotal	33	972.7	102.1	28	865.5	104.1
Amherst	1990	5	970.0	90.8	33	932.7	91.7
	1991	22	1015.9	130.5	29	889.4	80.7
	Subtotal	27	1007.4	123.9	62	912.8	88.8
Totals		122	955.9	108.2	124	887.9	92.4

on radio-marked juveniles found dead prior to hunting. Preseason dispersal was that proportion of the sample which left the immediate study area beyond a 25 km radius of the natal wetland before hunting in October. Many of those early dispersers were lost and presumed to have moved out of the Upper Bay of Fundy region. The extent of aerial coverage varied by study area. At Lepreau, where preseason dispersal was greatest, I searched much of southeastern New Brunswick and part of northern Maine. At Amherst, where most radio-marked Black Ducks remained in the immediate area, aerial search seldom went further than 25 km from the sanctuary. At Shepody, where preseason dispersion was moderate, the area of search included the Fundy coast of New Brunswick, the Northumberland Strait and parts of Prince Edward Island and northern Nova Scotia.

The sample available for hunting included those radio-marked juveniles known to be alive (excludes preseason dispersers) on opening day of the hunting season at respective study sites. The shot and retrieved samples were those recovered from hunters directly or those reported to CWS by the hunters. Radio-marked Black Ducks shot and not retrieved by hunters were recovered by CWS field personnel. These included both dead (unretrieved kill) and crippled birds. Post-season predation included those found dead during and following the hunting season for which the cause of death was identified as predation. Those presumed alive on 1 December and 1 January included those still under surveillance and those which are presumed to have dispersed before (preseason dispersers) and during (postseason dispersers) the hunting seasons.

I used Chi-square tests to compare the sex ratios of samples, rates of preseason dispersal by sex and age, intersite differences in losses to hunting and between-sex differences to losses from predation. I compared weights of males and females with a 2-tailed t-test.

Results

The Samples

Excluding ducks with transmitters that were known to have failed or fallen off, sample sizes of radio-marked juvenile Black Ducks at Shepody, Lepreau and Amherst Point were 96, 61 and 89, respectively (Table 1). The sex ratio favoured males at Shepody ($\chi^2 = 4.08$, $P < 0.05$), females at Amherst Point ($\chi^2 = 6.42$, $P < 0.02$), and was even at Lepreau ($\chi^2 = 0.20$, $P > 0.05$).

Although I made every effort to ensure that differences among annual and site-specific samples were minimal (e.g. all HY juveniles used in the samples weighed ≥ 750 g), there were some minor discrepancies. Males at Shepody weighed less than males at Amherst Point ($t = 3.13$, $P < 0.005$) and Lepreau ($t = 2.28$, $P < 0.05$) but there was no difference

($t = 1.16$, $P > 0.05$) between the mean weights of males at Lepreau and Amherst Point (Table 1). Females at Amherst Point were heavier than females at Shepody ($t = 2.99$, $P < 0.005$) and Lepreau ($t = 2.09$, $P < 0.05$) but there was no difference ($t = 0.20$, $P > 0.05$) between the weights of females at Shepody and Lepreau. There were no between-year differences in mean weights of males or females at Amherst Point or Lepreau but at Shepody, both males ($t = 2.69$, $P < 0.02$) and females ($t = 2.37$, $P < 0.02$) were heavier in 1988. I do not consider these differences as contributing factors in subsequent comparative measurements of habitat use or rates of mortality among the samples.

Preseason Predation

Preseason predation was highest at Shepody (14.5%) and lowest at Amherst Point (3.3%) ($\chi^2 = 40.0$, $P < 0.01$). Preseason predation at Lepreau (9.8%) was similar to the overall rate of 9.3% (Table 2). Preseason predation was greater on males (13.1%) than on females (5.6%) ($\chi^2 = 3.21$, $P < 0.05$). Sources of preseason mortality at the three study sites were: Shepody - Great Horned Owl (*Bubo virginianus*) 7, Marsh Hawk (*Circus cyaneus*) 2, Mink (*Mustela vison*) 1, unknown 4; Amherst Point - Great Horned Owl 1, Mink 1, unknown 1; Lepreau - Great Horned Owl 1, Mink 4, unknown 1.

Preseason Dispersal

Movement by radio-marked juvenile Black Ducks from managed marshes before hunting in early October was low at Shepody (4.2%) and Amherst Point (1.1%) (Table 2). At Lepreau, 26.2% of the sample dispersed from southern New Brunswick before hunting and were not relocated. On opening day of hunting at Lepreau, only 32.7% of the marked sample remained on wetlands within 10-15 km of the natal marsh. Thirty-one percent (19 of 61) of the sample had moved to coastal wetlands along the Bay of Fundy 25-50 km from the Lepreau site; thirteen of the 19 (68%) occupied a managed freshwater wetlands (Musquash) and adjacent saltmarsh and tidal flats 20-25 km from their inland natal wetlands. Two (3.2% of the sample) moved into wetlands 30 km north on the St. John River. There was no difference in the rate of preseason dispersal between males (9.8%) and females (7.3%) ($\chi^2 = 0.24$, $P > 0.05$). A greater proportion of juveniles produced on unmanaged wetlands (Lepreau) dispersed >10 km from their natal wetlands prior to hunting than did juveniles produced on managed wetlands (Shepody and Amherst Point) ($\chi^2 = 117.1$, $P < 0.001$).

Hunting Mortality

Mortality from hunting during October-November at Shepody, Amherst Point and Lepreau (excluding preseason dispersers) was 56%, 48% and 30%, respectively (Table 3). The proportion of

TABLE 2. Fate of juvenile Black Ducks radio-marked at three study sites in Atlantic Canada, 1987–1991.

Study site	Years	Sex	Sample size	Fate of radio-marked sample						Alive 1 December	Shot on wintering grounds in December	Presumed alive on 1 January	Total mortality from hunting
				Preseason predation	Preseason dispersion	Available to be shot	Retrieved	Total shot	Post-season predation				
Shepody 1987–1988	M	F	62	12	1	49	15	10	4	21	4	17	29
			34	2	3	29	13	6	1	12	1	11	20
			96	14	4 ^b	78	28	16	5	33	5	28	49
Lepreau 1989–1990	M	F	33	3	10	20	7	2	0	21	0	21	9
			28	3	6	19	3	0	0	22	0	22	3
			61	6	16 ^{b,c}	39	10	2	0	43	0	43	12
Amherst 1990–1991	M	F	27	1	1	25	9	3	0	14	4	10	16
			62	2	0	60	21	8	1	30	4	26	33
			89	3	1 ^{b,c}	85	30	11	1	44	8	36	49
All areas (1987–1991)	M	F	122	16 ^a	12	94	31	15	4	61	8	53	54
			124	7 ^a	6	111	37	14	2	66	5	61	56
			246	23	18	205	68	29	6	127	13	114	110

Hunting seasons: Shepody and Lepreau = 1 October–20 December (2 week delayed season along Fundy Coast); Amherst Point = 8 October 8–30 December. Values with similar superscripts significantly different ($P < 0.05$).

radio-marked juveniles shot but not retrieved at the three study sites was 36%, 27% and 16%. There were no between-year differences in proportions lost to hunting at Shepody and Amherst Point. At Lepreau, where sample sizes were lowest, a higher proportion was shot in 1989 than in 1990 (Table 3). There were no significant differences in the proportions of males and females lost to hunting at the three study sites. There was no difference in the total proportion of radio-marked juveniles lost to hunting at Shepody (56%) and Amherst Point (48%) ($\chi^2 = 0.78$, $P > 0.05$). The proportion lost to hunting at Lepreau (30%) was significantly less than at Shepody ($\chi^2 = 22.85$, $P < 0.005$) but not at Amherst Point ($\chi^2 = 2.65$, $P > 0.05$). The latter test was near significance, suggesting that mortality from hunting on juveniles produced on unmanaged freshwater wetlands in forested habitat is lower than mortality from hunting on juveniles produced on managed wetlands, even on wetlands given sanctuary status.

Further evidence for this can be seen from the distribution of deaths from hunting at Lepreau. Only two of 12 (16.6%) lost to hunting were shot on unmanaged freshwater wetlands of the interior study area. Six of 12 (50%) were shot on a managed wetland at the mouth of the Musquash River 20–25 km from interior natal wetlands. The six shot at Musquash represented a 46% mortality of the 13 radio-marked Lepreau juveniles known to have moved into the Musquash area prior to hunting. That mortality is similar to rates for juveniles on managed wetlands at Amherst Point (48%) and Shepody (56%) ($\chi^2 0.14$, $P > 0.05$).

Mortality from hunting continued through December as juveniles migrated south to coastal wintering areas in southwestern Nova Scotia and north-eastern United States. Eight of 44 (18.1%) radio-marked juveniles which migrated from Amherst Point were shot in December as were 5 of 33 (15.1%) which migrated from Shepody. No recoveries from the Lepreau sample were reported in December. The total known mortality rates from hunting on radio-marked juveniles presumed alive (includes preseason dispersers) and available for hunting at Shepody, Amherst Point and Lepreau were 59.8%, 56.9% and 21.8%, respectively (Table 2).

Postseason predation

Mortality from predation during the first two months of hunting (October–November), similar to predation before hunting, varied among the study sites (Table 2). The highest rate was at Shepody (6.4% of sample available for hunting). Only 1 of 85 (1.2%) died from predation at Amherst Point and 0 of 39 at Lepreau. At Shepody, two deaths were attributed to mink, one to owl and two to unknown predators. The one predation at Amherst Point was by an unidentified avian predator.

TABLE 3. Impact of hunting (October–November) on radio-marked juvenile Black Ducks captured on natal wetlands at three study sites in Atlantic Canada 1987–1991, and available for hunting on opening day.

Study site	Year	Sex	Sample size on opening day	Proportion shot		Total	Crippling loss
				Retrieved	Not retrieved		
Shepody	1987	M	25	0.28	0.28	0.56	0.50
		F	16	0.50	0.06	0.56	0.11
		Subtotal	41	0.36	0.19	0.56	0.34
	1988	M	21	0.38	0.14	0.52	0.27
		F	16	0.31	0.31	0.62	0.50
		Subtotal	37	0.35	0.21	0.56	0.38
	1987-88	M	46	0.32	0.21	0.54	0.40
		F	32	0.40	0.18	0.59	0.31
	Totals		78	0.35	0.20	0.56 ^b	0.36
Lepreau	1989	M	8	0.50	0.12	0.62	0.20
		F	4	0.50	0.00	0.50	0.00
		Subtotal	12	0.50	0.08	0.58 ^a	0.14
	1990	M	12	0.25	0.08	0.33	0.25
		F	15	0.15	0.00	0.15	0.00
		Subtotal	27	0.14	0.03	0.18 ^a	0.20
	1989-90	M	20	0.35	0.10	0.45	0.22
		F	19	0.15	0.00	0.15	0.00
	Totals		39	0.25	0.05	0.30 ^b	0.16
Amherst Point	1990	M	5	0.40	0.20	0.60	0.33
		F	31	0.32	0.13	0.45	0.28
		Subtotal	36	0.33	0.14	0.47	0.29
	1991	M	20	0.35	0.10	0.45	0.22
		F	29	0.38	0.14	0.52	0.27
		Subtotal	49	0.37	0.12	0.49	0.25
	1990-91	M	25	0.36	0.12	0.48	0.25
		F	60	0.35	0.13	0.48	0.28
	Totals		85	0.35	0.13	0.48	0.27

^aMortality from hunting between years significantly different ($\chi^2 = 4.49$, 1 d.f., $P < 0.05$).^bProportion of samples lost to hunting between sites significantly different ($\chi^2 = 22.85$; $P < 0.005$).

Habitat Use and Fall Dispersal

By September, radio-marked juvenile Black Ducks at Amherst Point Sanctuary and Shepody NWA had dispersed locally (≤ 10 km) among the following three broad wetland types: (1) freshwater within natal marshes, (2) adjacent freshwater, and (3) coastal-estuarine. The main difference between the two managed sites was that natal marshes at Amherst Point Sanctuary were closed to hunting while at Shepody NWA hunting was allowed. Changes in distributions of radio-marked Black Ducks among the three habitat types began earlier, and were more pronounced, at Amherst Point than at Shepody.

At Amherst Point, distribution among types was similar between early and mid-September ($\chi^2 = 1.68$, $P > 0.05$) but by late September juveniles were found more often in coastal and adjacent freshwater habitat and less often in the sanctuary ($\chi^2 = 85.6$, $P < 0.001$). That trend continued through early October ($\chi^2 = 111.0$, $P < 0.001$) but was reversed by mid and late October. There was no change in the

use of adjacent freshwater between early and late October but more use was made of the sanctuary ($\chi^2 = 26.2$, $P < 0.001$) and less use of the coastal habitat ($\chi^2 = 7.11$, $P < 0.01$). Juveniles made more use of the coastal habitat ($\chi^2 = 55.1$, $P < 0.001$) and less use of the sanctuary ($\chi^2 = 30.4$, $P < 0.001$) from late October through November while use of adjacent freshwater wetlands remained the same ($\chi^2 = 0.09$, $P > 0.05$).

There was little variation in distribution of radio-marked juvenile Black Ducks among the three habitat types at Shepody during September and October. There was no difference ($\chi^2 = 0.54$, $P > 0.05$) in those distributions between the first 10 days of September and the latter 10 days of October. Between late October and mid-November, juveniles at Shepody made greater use of coastal ($\chi^2 = 9.1$, $P < 0.01$) and adjacent freshwater ($\chi^2 = 72.2$, $P < 0.001$) habitats and less use of managed natal wetlands ($\chi^2 = 15.5$, $P < 0.01$) within the National Wildlife Area.

Although the general patterns of fall dispersal from Shepody and Amherst Point were similar (Figure 1), the proportions of ducks leaving during specific intervals varied between areas, possibly influenced by subtle between-year weather conditions. At Amherst Point, 12 of 40 juveniles dispersed 1 October–20 November 1990–91, while at Shepody, 12 of 24 dispersed between 1 October and 17 November 1987–88. The remaining juveniles at Amherst Point dispersed between 21 November and 14 December and at Shepody between 18–28 November. At Lepreau, fall dispersal was not monitored closely due to logistical difficulties.

Fall dispersal was most closely monitored at Amherst Point in 1991. The final few Black Ducks left the study area 5–6 December when the daily mean temperature (Moncton airport 30 km west of study site) dropped from -5.3° on 4 December to -14.6° on 6 December (Annual Meteorological Summary, Moncton Airport, Environment Canada). Migration by some of these late migrants was direct to the southern coast of Nova Scotia. A juvenile female departed on 6 December and was shot at Shelburne, Nova Scotia on 7 December (230 km) and a juvenile female and two juvenile males which departed on 5 December were shot at Yarmouth, Nova Scotia (223 km) on 7, 7, and 12 December.

Discussion

Juvenile Black Ducks produced on managed wetlands in Atlantic Canada tended to remain on or near those natal wetlands from fledging in August through fall migration in late November and early

December. These managed marshes, especially when located adjacent to coastal and estuarine habitats, provide young Black Ducks with the food resources required for rapid body growth and fat deposition in preparation for migration to southern wintering grounds, in contrast to most unmanaged wetlands in more remote forested habitats (see Erskine 1987; Parker et al. 1992). There is little reason for post-fledging dispersal as the immediate area also serves as fall staging habitat.

Juveniles produced on inland freshwater ponds and streams in forested habitat dispersed to more productive habitat shortly after fledging. Large freshwater marshes on rivers and coastal and estuarine habitats were often used for late summer and fall staging. Managed wetlands, especially adjacent to the coast, are also used for staging by juvenile Black Ducks produced on unmanaged and less fertile inland breeding and brood-rearing sites. In this study, many juveniles fledged on unmanaged wetlands dispersed entirely from the upper Bay of Fundy region; the fate of those marked juveniles is unknown. Large managed marshes at Shepody were used by juveniles until freezing in early November, whereas juveniles fledged on smaller managed wetlands at Amherst Point Sanctuary readily frequented the adjacent unmanaged streams and coastal and estuarine habitats.

At Amherst Point, some juveniles never left the sanctuary until fall migration, some regularly commuted to adjacent wetlands, and others moved from the sanctuary into nearby wetlands shortly after fledging and never returned. At Amherst Point, and to a lesser degree at Shepody, there was a noticeable shift in distributions during October from adjacent coastal habitat back into the managed marshes. This shift coincided with the opening of hunting. Protection from hunting afforded by the sanctuary may explain the greater use of managed marshes in October at Amherst Point. Whereas 80% of losses from hunting at Shepody were in the first five days of the season, only 39% were in the first five days of the season (one week later) at Amherst Point (Figure 2). However, there was little change in the use of adjacent freshwater wetlands where most of the mortality occurred. The shift appeared to be from coastal habitat, where mortality from hunting was light, back into the sanctuary. The less obvious shift in distributions during October at Shepody suggested that hunting did not significantly influence dispersal or habitat use at that site. Most hunting at Shepody occurred during the first two weeks of the season (1–15 October). The initial disturbance from hunting served to influence Black Duck behaviour and local movement patterns rather than disperse them from the area entirely. At Shepody, Black Ducks increased their use of secluded and less accessible back-waters and frequently remained hidden in

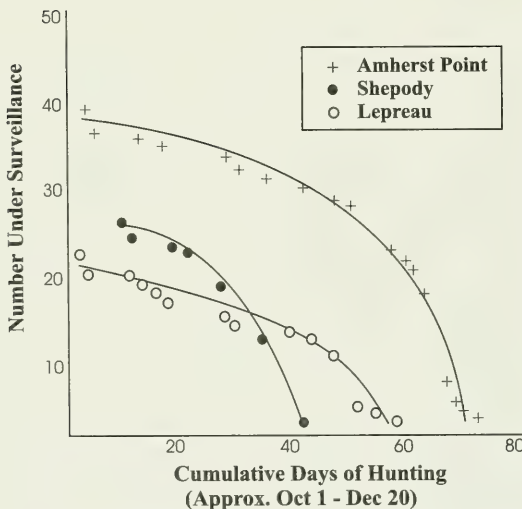


FIGURE 1. Dispersal (loss of radio contact) of surviving radio-marked juvenile Black Ducks from the three study areas during hunting season (showing approximate cumulative days of hunting).

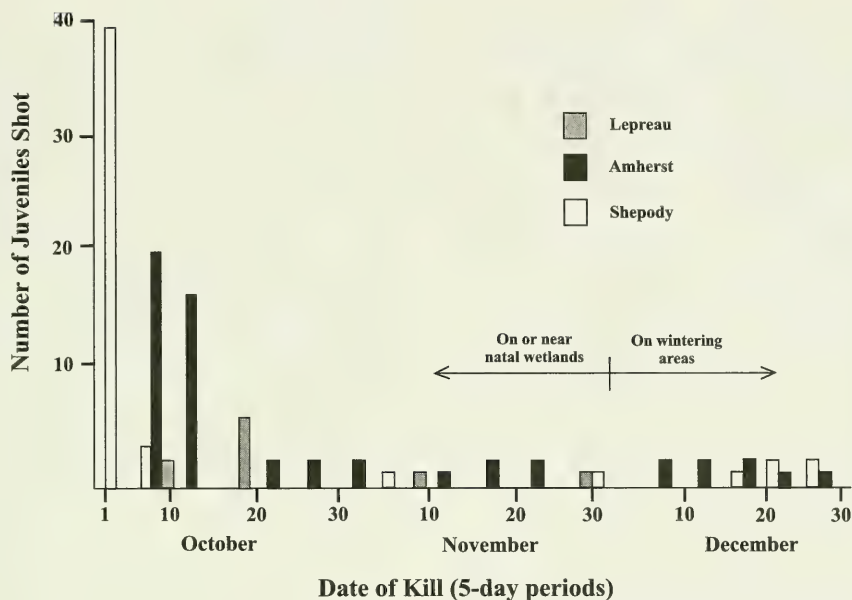


FIGURE 2. Temporal distributions of recoveries of radio transmitters by hunters at three study sites in Atlantic Canada (Shepody - 1987-88; Lepreau - 1989-90; Amherst Point - 1990-91).

vegetation rather than flushing at first disturbance.

Documented rates of predation on juvenile Black Ducks varied among the three sites. At Shepody NWA, 20% of the sample was subsequently killed (August-November) by avian or mammalian predators, very similar to the loss of radio-marked HY juvenile Black Ducks to predators during an approximate same time period in a study in and around the Moosehorn National Wildlife Refuge of northern Maine (Longcore et al. 1991). Predation on the sample from unmanaged wetlands at Lepreau, however, was very low (4.5%), suggesting that managed wetlands, such as at Shepody NWA, not only attracts breeding waterfowl and waterfowl hunters, but avian and mammalian predators as well. Predation on the sample of HY juveniles radio-marked on the managed wetlands at Amherst Point Sanctuary was 10%.

Hunting was the single most important source of mortality of juvenile Black Ducks at all three study sites. The similarity in mortality (October-November) from hunting on juveniles produced on a managed marsh subjected to heavy hunting pressure (Shepody - 56%) and a managed marsh given sanctuary status (Amherst Point - 48%) was unexpected. The high loss at Shepody was not surprising. The 162 hunters checked at Shepody on opening day in 1988 represented some of the heaviest duck hunting pressure (1 hunter/4.8 ha wetland) measured in Atlantic Canada, and the proportion of juveniles lost to hunting, relative to the region in general, is considered high. Since that study, regulations restricting hunting hours and spacing of blinds have substantial-

ly reduced hunting pressure at Shepody. Amherst Point Sanctuary is a relatively small freshwater wetland within an extensive coastal and freshwater wetland complex on the Tantramar marshes at the head of the Bay of Fundy. Waterfowl are protected within the sanctuary but are subjected to moderate and prolonged hunting pressure in adjacent managed and unmanaged wetlands until fall migration.

From this study it appears that the size of a management unit, and its juxtaposition with other managed or unmanaged wetlands, are important factors which influence the contribution of hunting to total mortality of juvenile Black Ducks. The day prior to hunting at Shepody in 1987 and 1988, 86% of radio-marked juveniles ($n = 70$) were on managed but unprotected marshes within the NWA whereas at Amherst Point only 28% ($n = 76$) were within the protected boundaries of the sanctuary prior to hunting. Available wetlands at Amherst Point Sanctuary have only 1/3 the total area of those available at Shepody NWA.

The loss to hunting of juveniles from Amherst (18%) and Shepody (15%) on wintering grounds in December was not exceptionally high, but contributed significantly to the total known loss to hunting on samples from both managed sites (Amherst Point - 56.9%; Shepody NWA - 59.8%). Mortality of juvenile Black Ducks from other sources (e.g. predation, environmental stress, etc.) would have to be substantial for such high rates of mortality from hunting to be totally compensatory. In contrast, the relatively low mortality from hunting (21.8%) on juveniles

produced on unmanaged wetlands at Lepreau suggests that those losses might be totally or partially compensatory to other forms of mortality.

Although I acknowledge that the behaviour of radio-marked ducks may differ from that of other similar but unmarked ducks, and thus be more susceptible to being shot, none of the hunters who shot radio-marked juvenile Black Ducks in this study reported any such obvious behavioural differences. In fact, no hunter interviewed knew that a duck carried a radio transmitter until it was retrieved. Although there is evidence that radio transmitters attached by harnessed backpacks may adversely influence the nesting effort, nesting success and subsequent recruitment of adult female Mallards (Pietz et al. 1993; Rotella et al. 1993; Paquette et al. 1997), no such evidence for behavioural changes exist for similarly marked HY juvenile Black Ducks during late summer and autumn (Frazer et al. 1990a; 1990b; Longcore et al. 1991; Parker 1991), as for this study, or during the winter months (Conroy et al. 1989). Even if subtle but undetected differences in behaviour did exist between our samples of radio-marked HY Black Ducks and other unmarked Black Ducks in the population, differences which may have made the marked sample more susceptible to being shot by hunters, the process of comparing *relative* rates of mortality of radio-marked HY Black Ducks produced on managed and unmanaged wetlands remains valid.

Enhancement of wetlands for waterfowl production on northern breeding grounds, with the objective of increasing recruits into local and regional populations, especially Black Ducks, has been considered a valid management option. However, given the attraction to managed wetlands by both waterfowl and waterfowl hunters, management strategies should be flexible and site specific. Site, location and availability of peripheral or adjacent unmanaged freshwater and coastal-estuarine habitats should be considered when developing management strategies. For most managed wetlands a degree of conservatism during hunting should be exercised.

I acknowledge that the implications for regional breeding Black Duck populations from the attraction of hunters to managed wetlands may be two-edged. Although mortality from hunting on juvenile Black Ducks on such areas may appear high, most of those ducks shot are a result of recent management efforts. The attraction of hunters to these small managed wetlands does serve to decrease or eliminate hunting pressure on many of the more inaccessible unmanaged wetlands. The caveat to this scenario may be the attraction of juveniles to managed wetlands, and concentrated hunting pressure, from peripheral unmanaged landscapes, as suggested by the pre-season distribution of radio-marked juvenile Black Ducks at Lepreau. More information is needed on whether managed wetlands serve as sinks, sources or buffers to local and regional breeding waterfowl populations.

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The Status of the Eastern Sand Darter, *Ammocrypta pellucida*, in Vermont

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Four major tributaries of Lake Champlain support populations of Eastern Sand Darter (*Ammocrypta pellucida*) in Vermont — the Poultney River (which forms part of the border between Vermont and New York), the Winooski River, the Lamoille River, and the Missisquoi River. The Eastern Sand Darter inhabits areas with sandy substrate in the lower portion of these rivers (below the first dam). In most cases, the fish were found in shallow water with low velocity, and often along the downstream portion of sand bars along the depositional side of a bend in the river. Length-frequency distribution histograms suggest two or three age classes. The youngest class (presumably young-of-the-year) was underrepresented, probably due to sampling gear bias. Repeated sampling at one site in the Winooski River during May and June of 1995 suggested that spawning took place between 6 June and 26 June, when water temperatures were between 20.5 and 25.5°C. The Eastern Sand Darter appears to be quite specific to fine sand substrates. Therefore, upstream flow alteration or land use practices that are likely to result in removal or silting-over of sandbars, or vegetative encroachment on those sandbars, is likely to reduce habitat for this species.

Key Words: Eastern Sand Darter, *Ammocrypta pellucida*, Lake Champlain, St. Lawrence River drainage, Vermont.

Holm and Mandrak (1996) recently reported on the status of the Eastern Sand Darter (*Ammocrypta pellucida*) in Canada. Their paper indicated that the species had been found at several sites in the main channel of the Richelieu River during surveys in 1970, but that no sampling had taken place in the Richelieu from 1970 to 1995. No Eastern Sand Darters were found during an electrofishing survey of 21 sites in the Richelieu River in the summer of 1995 (N. La Violette, personal communication). Holm and Mandrak (1996) also reported that in the early 1980s Eastern Sand Darters had been captured in several tributaries of the St. Lawrence River near the Richelieu River, including the Becancour, Petite, and Originaux rivers. Apparently these areas have not been sampled since 1982. These locations seem to represent the northeasternmost extension of the species in North America.

The Richelieu River drains Lake Champlain, most of which lies on the border between the U.S. states of Vermont and New York (Figure 1). Therefore, populations of Eastern Sand Darter located in Lake Champlain or its tributaries represent a southern extension of the St. Lawrence population, which is disjunct from the rest of the species' range. In this paper I report the results of surveys of the Eastern Sand Darter in Vermont tributaries of Lake Champlain.

The Eastern Sand Darter's range extends from the St. Lawrence River and the Lake Champlain drainage southwesterly to southwestern Ontario, southeastern Michigan, and throughout much of the Ohio River basin to West Virginia and Kentucky. The species is conspicuously absent from the Lake

Ontario drainage and central New York (Page 1983; Page and Burr 1991). Williams (1975) speculates that this absence from the Lake Ontario system may be due to an absence of available habitat or "... extirpation resulting from alteration of existing habitat...". However, Smith (1985) suggests that the species may have reached Lake Champlain, and subsequently the St. Lawrence, through "...glacial connections in the Mohawk Valley and glacial Lake Albany, although a more northerly route is possible."

Historical information suggests that there has been a decrease in the abundance of this species throughout much of its range. Daniels (1993) indicated that large populations had been reported in some early surveys (e.g., Woolman 1890; Kirsch 1894a,b), whereas more recent surveys (e.g., Hendricks 1985; McKeown 1986*) found fewer or no individuals. Even as early as the 1950s, Trautman (1957) reported that Eastern Sand Darters were much less common in Ohio than they had been before 1945. Trautman (1981) further illustrated this trend in Ohio by reporting that despite widespread effort, Eastern Sand Darters had been collected at only about 12 sites between 1954 and 1980. The species had been found at approximately 80 sites in collections made prior to 1924, and at almost 90 sites in collections made between 1924 and 1954.

This decline in Eastern Sand Darter populations probably is due to habitat degradation caused by agricultural and industrial pollution, channelization,

*Unpublished. See Documents Cited Section.



FIGURE 1. Map of Lake Champlain, indicating Vermont rivers known to support populations of Eastern Sand Darters (*Ammocrypta pellucida*).

impoundments, and siltation (see Clay 1975; Scott and Crossman 1973; Smith 1979; Smith 1985; Daniels 1993). Several land use practices result in increased siltation of rivers and streams, making formerly sandy areas no longer suitable for Eastern Sand Darters (Scott and Crossman 1973; Smith 1985; Daniels 1993; Holm and Mandrak 1996).

It is also possible that recent improvements in water quality in some areas, particularly decreases in silt loads, have expanded suitable habitat for the Eastern Sand Darter. Daniels (1993) mentions that Greeley (1930) reported no Eastern Sand Darters found during a 1929 survey of the Mettawee River (New York) and Poultney River (New York-Vermont). Field notes apparently indicated that both rivers had mud bottoms. Sandy stretches of both of these rivers now support viable populations of Eastern Sand Darter (Daniels 1989, 1993; Bouton 1991).

There is almost no historical information about the occurrence of Eastern Sand Darters in Vermont. The

University of Michigan Museum of Zoology has two preserved specimens (UMMZ catalogue number 102885) from a 1934 collection in the Lamoille River (see Figure 1). Collection information indicates that the fish were sampled about 4 miles upstream from the river's mouth. This location corresponds to a large bend in the river that now has a large sandbar on the north shore. Unfortunately, museum records do not indicate the total number of Eastern Sand Darters caught in that 1934 sample, so we have no way of knowing how abundant the species was at that time. Perhaps more than two specimens would have been preserved if the species had been abundant, but we can't be sure. In July of 1989, seining by Vermont Fish and Wildlife personnel on a large sandbar at that same site yielded 96 Eastern Sand Darters.

Eastern Sand Darters were caught in the Poultney River in the early to mid 1980s. Thomas French of The Nature Conservancy reportedly caught 12 in July of 1983, and Dean Bouton of the New York State Department of Environmental Conservation caught five in August of 1984 (Bouton 1986).

In the mid to late 1980s, several large surveys of fishes in Lake Champlain tributaries were conducted, primarily to gather information needed to make recommendations regarding control of Sea Lamprey (*Petromyzon marinus*) in those rivers and streams that supported large Sea Lamprey populations. Eastern Sand Darters were found in sandy stretches of the Missisquoi, Lamoille, Winooski, and Poultney rivers.

In this paper I summarize data collected from several surveys of Eastern Sand Darter populations in the Missisquoi, Lamoille, Winooski, and Poultney Rivers from the late 1980s to the present.

There has been some dispute regarding the proper scientific name of the Eastern Sand Darter. Although arguments have been made that the species name should be changed from *Ammocrypta pellucida* to *Etheostoma pellucidum* and the latter name has appeared in some printed sources (e.g., Page and Burr 1991), the American Fisheries Society Committee on Names of Fishes recognizes *Ammocrypta pellucida* as the accepted scientific name. In addition, Simon et al. (1992) argue that apparent similarities between *Ammocrypta* and *Etheostoma* are likely due to convergent evolution and that the genera should remain separate.

Methods

Inventories in the Missisquoi, Lamoille, and Winooski Rivers in the mid-1980s were conducted by Vermont Department of Fish and Wildlife and University of Vermont personnel and incorporated the use of electrofishing or a minnow seine. The 1987-1991 survey work in the Poultney River was conducted by New York Department of

Environmental Conservation personnel and utilized a bag seine with 1.2 m \times 3.7 m wings (0.64 cm Delta mesh), and 1.2 m \times 1.2 m \times 1.2 m bag (0.48 cm Ace mesh).

I conducted surveys during July, August, and September of 1993 and 1994 in the Missisquoi, Lamoille, and Winooski rivers, using a bag seine with the same dimensions as the one used in the Poultney River surveys. In addition, I repeatedly sampled one Winooski river site in 1995 during the months of May through September. The lower section of each of these rivers (below the first dam) was traveled by boat or canoe and any areas that appeared to have primarily sandy substrate were sampled. Nearby and adjacent sites sometimes were sampled, which included shallow areas with muddy, gravelly, or silty substrates and some sites with aquatic vegetation. All areas were sampled beginning on the downstream end and moving upstream.

I measured the standard lengths [SL] (from tip of nose to base of tail), of most Eastern Sand Darters captured before the fish were released. In one case, only 50 of 145 Eastern Sand Darters captured were measured so that they could all be released before being subjected to excessive stress. Total lengths [TL] (from tip of nose to end of tail), also were available from two 1989 surveys in the Lamoille River (Vermont Fish and Wildlife Department) and one 1991 survey in the Poultney River (New York Department of Environmental Conservation). I converted these measurements to standard lengths using $SL = 0.87 \times TL$, a conversion factor which I determined by measuring both standard and total lengths of 18 Eastern Sand Darters.

Results and Discussion

Viable populations of Eastern Sand Darter seem to be fairly well established in the Missisquoi, Lamoille, Winooski, and Poultney rivers. Unfortunately, the paucity of historical information makes it impossible to assess whether or not these populations have changed significantly over the years.

Eastern Sand Darters were found in nearly every area of apparently suitable habitat that was sampled. Additional detailed information, including maps of locations within each river, site descriptions, and counts and density estimates at each site are provided in Bouton (1991*) and Facey (1995*). Bouton (1991*) also provides some information on Eastern Sand Darters caught in the Salmon River, New York from 1987 to 1991. In addition, 1995 surveys of the Mettawee River (New York) found that Eastern Sand Darters were still present in the same areas that they had been sampled in the early 1980s (R. Daniels, personal communication).

Habitat

Eastern Sand Darters were found in areas with fine, sandy substrates with very little, if any, weeds, mud, or coarse gravel. They were not captured in deeper, swifter areas characterized by coarser sand. During the 1993 and 1994 surveys, I found that the most productive areas often were near shore, had soft sand substrate, and were located along the depositional bank on the downstream side of a bend in the river. This was further corroborated in discussions with Dean Bouton, who conducted the Poultney River surveys from 1987–1991. Water depth was usually less than 0.5 m, and velocity in these areas was usually fairly low.

Extensive observations and sampling in the Mettawee River, New York, in 1982 and 1984 showed that Eastern Sand Darters were found only in areas with substrates that were at least 90% sand (Daniels 1993). Most fish were caught or observed within 20 m downstream of a bend in the channel, on the depositional side of the river, within 5 m of shore, in water less than 0.5 m deep and with a mean water-column velocity of less than 20 cm/sec. This study of Mettawee River fish is particularly relevant to Vermont and Quebec populations because the river is a tributary of Lake Champlain. The Mettawee River study also included identifying and enumerating all other fishes caught and found no significant positive correlation between the occurrence of Eastern Sand Darters and any other species. Daniels' study also included observations of Eastern Sand Darters in an artificial stream. He observed that 90% of all individuals selected sand (0.25–0.5 mm particle size) over gravel (1–2 cm) or rubble (8–15 cm). Clearly, this species is quite specific in its habitat needs, requiring soft sandy substrates in areas of relatively low to moderate velocity.

Other field studies also have indicated that the Eastern Sand Darter shows a preference for fine sand substrate (Daniels 1989; Holm and Mandrak 1996). Smith (1985) stated that these areas should have "...currents slow enough to retain sand but fast enough to prevent deposition of fine silt." In Lake Erie, Eastern Sand Darters have been caught in some wave protected areas with sandy shoals (Langlois 1954; Hendricks 1985).

Eastern Sand Darters reportedly bury themselves in sandy substrate (Daniels 1989). It had been suggested that this burying behavior is an effort to avoid predation (Jordan and Copeland 1877), hide from potential prey (Trautman 1981), or conserve energy (Williams 1975). Results of experiments in an artificial stream did not support the first two hypotheses (Daniels 1989). Daniels concluded that this behavior may be an effort to conserve energy and maintain position on the rather homogeneous sandy areas in which the fish live.

One rather striking result of the multiple year

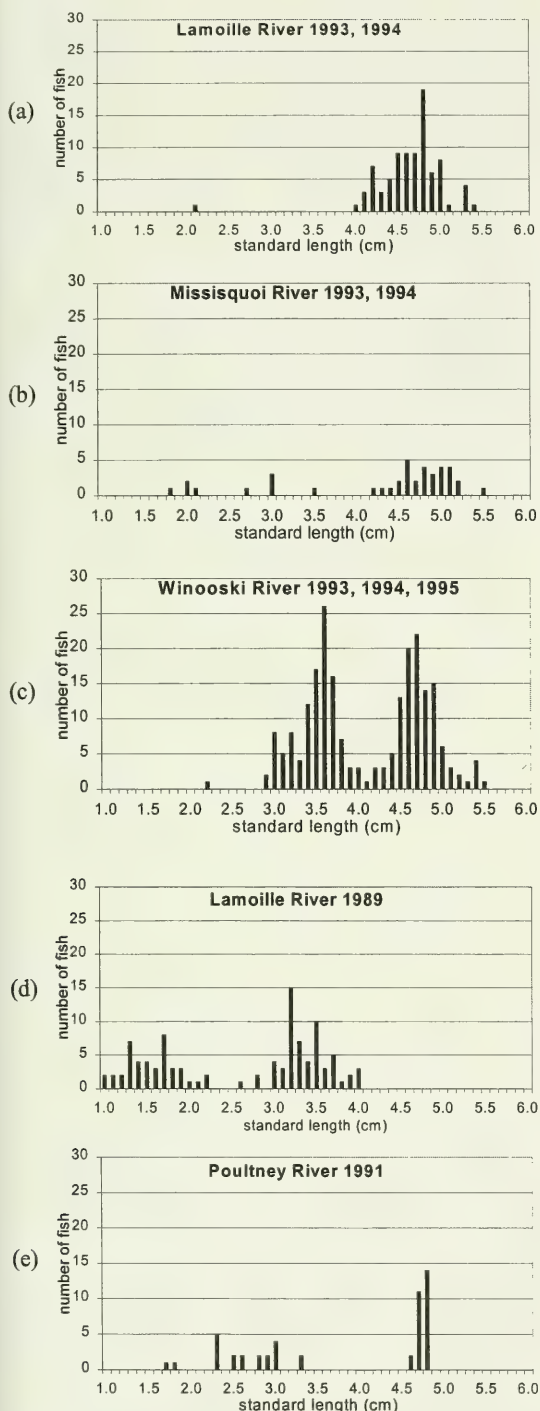


FIGURE 2. Length — frequency distribution of Eastern Sand Darters (*Ammocrypta pellucida*) captured in (a) the Missisquoi River in 1993 and 1994; (b) the Winooski River in 1993, 1994, and 1995; (c) the Lamoille River in 1993 and 1994; (d) the Lamoille River in 1989; and (e) the Poultney River in 1991.

study of the Poultney River (Bouton 1991*), was the year-to-year fluctuation in the number of fish caught and the fish density at each of the sampling sites, which in some cases changed by as much as 5–10 fold. For example, one site (site 14) had nearly 32 fish per 100 square meters in 1987, then dropped to 8.5 in 1988, 1.5 in 1989, rebounded to 3.2 in 1990, and 22.2 in 1991. Another site (site 18) went from 27.8 fish per 100 sq. meters in 1987 to 0 in 1988, 4.9 in 1989, 0.1 in 1990, and up to 41.7 in 1991. Many of the other sites show similar inconsistency in population densities from year-to-year. The number and distribution of Eastern Sand Darters surveyed in the Missisquoi, Lamoille, and Winooski Rivers in 1993 and 1994 also fluctuated considerably.

Possible explanations for this degree of population fluctuation include (1) dramatic swings in the levels of reproduction and recruitment; (2) instability of habitat conditions such as flow, depth, and substrate composition at the sites; (3) the fact that these fish select habitats that may not have a fixed location from year-to-year (sand bars do shift with flow); and (4) changes in flow and depth that might affect sampling effectiveness. Possible reasons behind this year-to-year variability is one area for future studies.

Length-frequency distribution

The length-frequency distributions of the Eastern Sand Darters from each river are shown in Figures 2a–2e. These histograms include converted 1989 data from the Lamoille River (Figure 2d), collected by biologists of the Vermont Fish and Wildlife Department, and 1991 data from the Poultney River (Figure 2e), collected by New York Department of Environmental Conservation personnel.

Considered collectively, the frequency histograms indicate what appears to be three distinct year classes. The youngest fishes, presumably young-of-the-year, were under 2.5 cm SL. These were generally uncommon, perhaps due to sampling gear bias. Collections in 1989 by Vermont Fish and Wildlife Department personnel (who used different gear), showed considerable representation of this youngest year class (Figure 2d). The second age class, presumably age I fish, were mostly between 3.0 and 4.0 cm SL. Many of the largest fish, presumably age II, were over 4.5 cm SL, although there were a few between 4.0 and 4.5 cm SL. The presence of multiple year classes, including young-of-the-year, indicates at least some degree of successful reproduction by these populations.

The sizes of the fish caught in Vermont correspond somewhat with the lengths of Eastern Sand Darters from Salt Creek, Ohio, in which age 0 fish were 18.8–41.2 mm SL (mean = 33.4); age I fish were 34.2–52.6 mm SL (mean = 44.4); and age II were 45.5–52.8 mm SL (mean = 48.8) (Spreitzer 1979*). The maximum age of fish in that study was 2+.

One might expect a length-frequency distribution histogram of a stable or growing population to show a large number of young individuals, with fewer individuals in older groups. Although the pattern of relatively few young individuals could be a sign of a declining population, it is more likely that this is an artifact of sampling bias. The combination of small size, thin bodies, and burrowing behavior make even the larger adults of this species difficult to sample. It is quite likely that the smaller, younger fish are simply escaping capture by slipping under or through the seines. The question of whether the length-frequency histograms indicate diminished reproduction or are a result of sampling bias is another good issue for future studies.

Spawning

Although spawning was not directly observed, multiple collections from a site in the Winooski River suggest that in 1995 spawning began in mid June. Females swollen with eggs were captured on 6 June 1995 (water temperature = 20.5°C), but fish caught on 26 June (water temperature = 25.5°C) did not have the same gravid appearance.

The breeding behavior of the Eastern Sand Darter apparently has not been studied in its natural habitat. There is, however, some information available regarding the apparent timing of spawning activity, as well as some observation of spawning in aquaria.

Johnston (1989) observed spawning in aquaria of Eastern Sand Darters taken from the Tippecanoe River in Indiana during June and July. Spawning occurred at temperatures of 20.5 to 23°C. Williams (1975) reported that spawning appears to take place from early June to late July in Ohio and that Great Lakes and St. Lawrence River populations appear to spawn two to three weeks later.

All available data and observations indicate that clean, soft, sandy substrate in shallow areas of relatively low current velocity are critical to the Eastern Sand Darter. It also is noteworthy that the best locations seem to be in meandering sections of large rivers, immediately downstream of bends in the river channel, in the shallow, relatively slow-moving water along sandbars on the depositional bank. Therefore, any significant disturbance of the shape of the channel or the sandbars created by the channel's meandering, land use changes that might increase siltation, or changes in river flow that might reduce the availability of sandbars would likely be detrimental to the species.

Several areas for future study could significantly enhance our understanding of the biology of the Eastern Sand Darter. These include (1) what physical characteristics are important in microhabitat choice; (2) reasons behind the year-to-year variability in Eastern Sand Darter abundance at many sites; (3) better information regarding reproduction and recruitment; and (4) the population genetics of the

species. Regarding this last point, it is interesting that the Eastern Sand Darters of the St. Lawrence - Lake Champlain drainage are geographically isolated from the rest of the species. It would be valuable to know how genetically similar or distinct they are from their conspecifics in the Great Lakes and Ohio River drainage, as well as how distinct populations within the St. Lawrence - Lake Champlain drainage are from one another.

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Déplacements et superficie du domaine vital de l'orignal, *Alces alces*, dans l'est du Québec

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Cinquante-sept orignaux (*Alces alces*) ont été suivis par télémétrie dans l'est du Québec entre 1989 et 1991. Les 1034 localisations réalisées ont permis de caractériser le patron de déplacement des orignaux juvéniles, des femelles adultes et des mâles adultes sur une base annuelle et en fonction de la période de l'année (i.e., été, automne, hiver). La population étudiée n'était pas migratrice et se caractérisait par des déplacements quotidiens faibles et des domaines vitaux de grande superficie. Les distances minimales parcourues furent en moyenne de 0,22 km/jour mais variaient considérablement d'un orignal à l'autre. Les déplacements quotidiens différaient ($P < 0,01$) entre les juvéniles (0,34 km/jour), les femelles adultes (0,14 km/jour) et les mâles adultes (0,20 km/jour) pour la période estivale. Les déplacements effectués à l'automne furent plus grands que les déplacements hivernaux, les valeurs respectives pour ces saisons dans l'ensemble de la population étant de 0,28 km/jour et 0,12 km/jour ($P < 0,05$). À l'été, les déplacements quotidiens minimaux prirent une valeur intermédiaire (0,21 km/jour). La superficie totale du domaine vital, estimée par le polygone convexe, fut en moyenne de 112 km² pour les femelles adultes, 131 km² pour les mâles adultes et 66 km² pour les juvéniles et ne différait pas entre les juvéniles et les adultes ni entre les sexes chez ces derniers ($P > 0,05$). Chez les femelles, les plus petits domaines vitaux (19 km²) ont été observés à l'automne. Le patron d'utilisation de l'espace par les orignaux de l'est du Québec pourrait être influencé par les faibles densités de population, l'absence de prédateurs efficaces, la rareté des plans d'eau et par la structure de la population, déséquilibrée par une chasse intensive.

Mots-Clés : Orignal, *Alces alces*, domaines vitaux, déplacements, Québec.

Fifty-seven Moose (*Alces alces*) were monitored by telemetry in eastern Québec between 1989 and 1991. The 1034 telemetry locations allowed characterization of the movement pattern of juvenile Moose and adults of both sexes on a seasonal and yearly basis (i.e. summer, fall, winter). The population was characterised by restricted daily movements, large home ranges, and non-migratory animals. The minimum daily movements varied considerably between individuals but were estimated at 0.22 km/day. Summer minimum daily distances differed significantly ($P < 0.01$) between juveniles (0.34 km/d), adult females (0.14 km/d) and adult males (0.20 km/d). Minimum daily movements were more important in fall (0.28 km/d) than in winter (0.12 km/d; $P < 0.05$). In summer, minimum daily movements were intermediate (0.21 km/d) compared to fall and winter values. The total home range size, as estimated with the minimum convex polygon, was 112 km² and 131 km² respectively for adult females and males and 66 km² for juveniles. On an annual basis, home range sizes did not differ ($P > 0.05$) between juveniles and adults, nor between adult males and females. For females, the smallest home ranges (19 km²) were noted in fall. The space utilisation patterns of Moose in eastern Québec could be influenced by the low population densities, the absence of efficient predators, the low incidence of lakes, and by the skewed sex-ratio towards females induced by heavy hunting.

Key Words: Moose, *Alces alces*, home range size, movements, Québec.

Plusieurs facteurs dont le type d'habitat, la saison, la présence de prédateurs, la structure de la population, le sexe et le statut social des individus influenceraient le patron d'utilisation de l'espace chez l'orignal (*Alces alces*; LeResche 1974; Courtois et Crête 1988; Cerderlund et Sand 1994; Van Dyke et al. 1995). Des domaines vitaux de grande superficie et des déplacements importants sont habituellement liés aux habitats morcelés ou pauvres dans lesquels les aires d'alimentation et de couvert sont dispersées (Lynch et Morgantini 1984; Courtois et al. 1993). De même, la superficie du domaine vital serait plus petite à l'hiver qu'à l'été (LeResche 1974) parce que

la neige entrave les mouvements des bêtes. À forte densité de population, les déplacements seraient plus grands à cause des interactions entre les individus (Courtois et Crête 1988) et la présence de prédateurs aurait un impact similaire (Ballard et al. 1980; Courtois et Crête 1988). Généralement, les jeunes individus de même que les orignaux qui colonisent un nouveau milieu (Garner et Porter 1990) exhibent un comportement exploratoire qui les amènent à se déplacer davantage que leurs congénères. Finalement, les mâles adultes ont généralement des domaines vitaux plus grands que les femelles et l'amplitude de leurs déplacements augmente pendant

le rut, lors de la recherche active de partenaires sexuels (Lynch et Morgantini 1984; Knowlton 1960; Houston 1968; Berg 1971; LeResche 1974; Garner et Porter 1990), ce phénomène étant plus important lorsque les femelles sont rares (Garner et Porter 1990).

L'objectif de notre étude est d'évaluer l'importance des déplacements et la superficie des domaines vitaux d'orignaux mâles et femelles en absence de prédateurs dans des sites où l'habitat est de bonne qualité mais où les densités sont faibles et le rapport des sexes déséquilibré en raison d'une chasse intensive.

Aire d'étude

Le travail a été réalisé dans trois blocs d'étude (Mitis, Dunière et Matapédia) de l'est du Québec (Figure 1), dans le domaine de la sapinière à bouleau blanc (Grantner 1966). Le territoire est dominé par les peuplements de conifères ou les mélangés à dominance de conifères. Les principales essences sont le sapin baumier (*Abies balsamea*), l'épinette blanche (*Picea glauca*), l'épinette noire (*Picea mariana*), le bouleau à papier (*Betula papyrifera*) et le bouleau jaune (*Betula alleghaniensis*). Au cours des 15 dernières années, le milieu forestier a été perturbé de façon importante par la tordeuse des bourgeons de l'épinette (*Choristoneura fumiferana*) et par des coupes

forestières qui prélèvent annuellement environ 1,1 % du couvert forestier. Les forêts jeunes occupent maintenant environ 33% du territoire (Ministère du Loisir, de la Chasse et de la Pêche 1993). Le Loup (*Canis lupus*), principal prédateur de l'orignal, est absent de la région étudiée. Le bloc Matapédia couvre une superficie de 416 km². Il s'agit d'un territoire public à accès libre pour la chasse, situé près de zones habitées. La récolte d'orignaux y est importante et la densité de cette espèce est faible (1 orignal/10 km²). Les blocs Mitis et Dunière occupent des superficies respectives de 1000 km² et de 1300 km². Ils sont situés en partie dans des territoires où l'exploitation par la chasse est limitée. La densité d'orignaux y est un peu plus élevée (1,5 orignaux/10 km²).

Méthodes

De 1989 à 1991, 57 orignaux ont été marqués et ont fait l'objet d'un suivi télémétrique. Les orignaux ont été immobilisés à la fin de mars et au début d'avril à l'aide d'un relaxant musculaire, le chlorure de succinylcholine, injecté grâce à une seringue projectile de 10 cc tirée à partir d'un hélicoptère de type Hughes 500D. Les dosages de relaxant étaient généralement de 5–6 mg par 100 kg de masse corporelle, mais ont varié selon la condition physique des individus. Les orignaux immobilisés ont été munis de colliers émetteurs VHF conventionnels

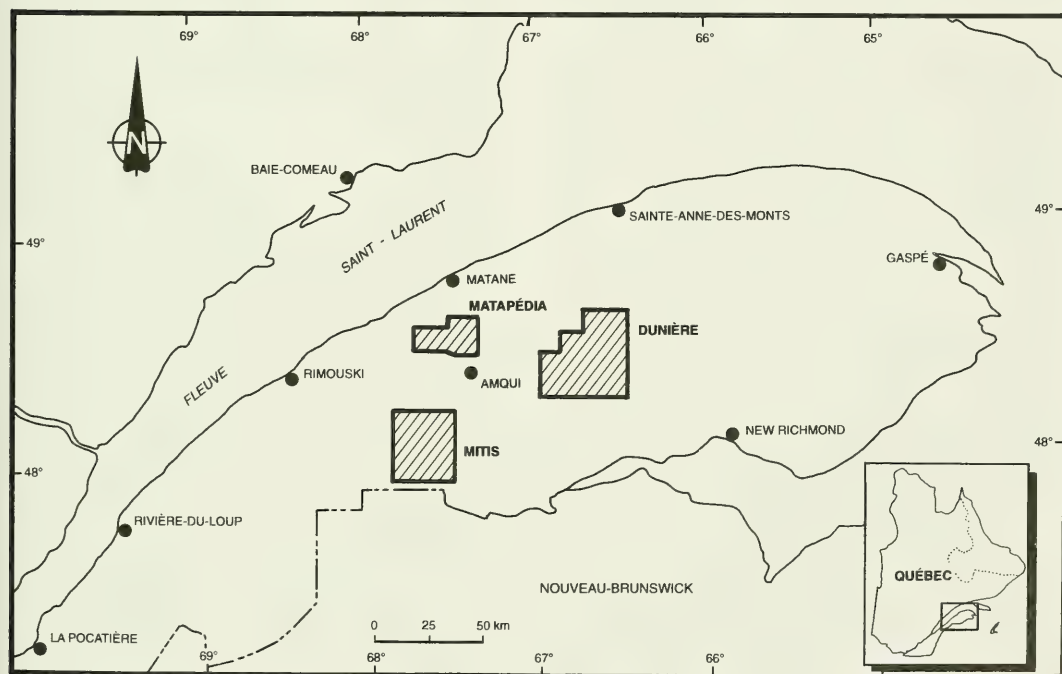


FIGURE 1. Localisation géographique des blocs Matapédia, Mitis et Dunière, dans l'est du Québec.

(LMRT-4, Lotek Engineering, Newmarket, Ontario).

Pendant les trois années de l'étude, 1034 localisations télémétriques ont été enregistrées, soit 18 positionnements par orignal en moyenne. Les repérages furent effectués mensuellement, à l'aide d'un petit avion monomoteur de type Cessna 172 auquel étaient fixées deux antennes directionnelles. Un commutateur permettait d'utiliser l'une ou l'autre des antennes pour faciliter les repérages. Lorsqu'un animal était détecté, l'avion décrivait des virées perpendiculaires permettant de localiser l'animal à environ 300 m près. Les positionnements étaient reportés sur des cartes topographiques 1: 50 000.

Les juvéniles (12 à 23 mois) et les adultes de chaque sexe furent traités séparément. Six originaux, marqués à 10–11 mois, font partie des deux catégories puisqu'ils ont été suivis pendant plusieurs années. Pour ces individus, les fichiers de données ont été scindés pour traiter séparément chaque groupe d'âge. Les déplacements et les domaines vitaux ont été évalués pour l'ensemble des repérages d'abord puis pour les périodes d'été (mai-août), d'automne (septembre-octobre) et d'hiver (novembre-avril).

La caractérisation des déplacements et des domaines vitaux a été faite sans distinction du bloc d'étude. Le test de Kruskal-Wallis a déterminé qu'il n'existait pas de différence significative entre les blocs pour les mâles adultes et les juvéniles. Dans le cas des femelles adultes, la superficie des domaines vitaux différait pour seulement deux des sept méthodes de calcul utilisées. Comme les effectifs étaient faibles, nous avons jugé nécessaire de grouper les données afin d'obtenir un échantillon suffisant pour étudier les changements saisonniers.

La distance quotidienne minimale, soit la distance linéaire entre deux localisations successives divisée par le temps (en jour) écoulé entre les deux repérages (Courtois et Crête 1988) a servi d'indice pour caractériser les déplacements entre les périodes considérées. Comme l'intervalle de temps entre deux localisations était quelque peu variable (moyenne \pm erreur type = $31,0 \pm 0,5$ jours; $n = 1030$), cette mesure doit être considérée simplement comme un indice de l'ampleur des déplacements. Cette approche est toutefois adéquate pour comparer les différences entre les individus et entre les groupes d'originaux puisque tous les animaux étaient repérés selon la même fréquence. De plus, une analyse de régression a montré que le temps entre deux localisations n'expliquait que 9 % de la variance des distances quotidiennes parcourues entre deux localisations ($P < 0,001$).

La superficie du domaine vital total des originaux a été estimée à partir du polygone convexe, du polygone concave, de l'ellipse à 95% et de la moyenne harmonique avec 50, 70, 95 et 100 % des localisations. Un seul domaine vital a été calculé pour les

animaux suivis sur plusieurs années, le nombre relativement restreint d'observations par animal empêchant de calculer un domaine vital annuel. Les sept méthodes précitées ont été utilisées pour faciliter les comparaisons avec la littérature (Harris et al. 1990; White et Garrott 1990). La superficie du domaine vital par période n'a toutefois été estimée qu'à l'aide du polygone convexe, l'indice le plus fréquemment cité dans la littérature (White et Garrott 1990). Les calculs ont été effectués à l'aide du logiciel McPaal V.1.2 (Stüwe et Blohowiak 1985).

Le nombre minimal de localisations requis pour obtenir une estimation non biaisée a été déterminé graphiquement pour chaque animal. On assumait que le nombre de repérages était suffisant pour obtenir une estimation valable lorsque la superficie du polygone convexe demeurait stable même si le nombre de localisations utilisées pour l'estimation augmentait. Généralement, un point d'inflexion était noté et la variance diminuait avec une vingtaine de localisations télémétriques (Figure 2). Ainsi, le domaine vital total a pu être estimé pour 22 femelles adultes, 10 mâles adultes et 9 juvéniles. Les localisations d'un mâle adulte montraient un déplacement important du centre d'activité en 1989. Pour cet animal, deux domaines vitaux séparés ont été calculés, mais seule l'estimation de 1989 fut retenue puisqu'elle seule possédait un nombre suffisant de localisations pour obtenir une estimation valable. La superficie du domaine vital par période fut estimée pour 19 femelles et huit mâles adultes. Le chevauchement des domaines vitaux d'été-automne et d'hiver a été estimé en calculant le pourcentage de la superficie totale commun aux deux saisons (Cederlund et Okarma 1988).

Les comparaisons statistiques furent réalisées par des tests non-paramétriques puisque les paramètres étudiés ne rencontraient pas les conditions d'application de l'analyse de variance. Les échantillons appariés ont été comparés par un test de Wilcoxon. Lorsque ces comparaisons impliquaient plus de deux médianes, le seuil de signification fut corrigé par la procédure de Bonferroni (Wilkinson 1989). Les échantillons indépendants ont été comparés par un test de Mann-Whitney ou de Kruskal-Wallis (approximation du chi carré) selon le nombre de comparaisons à effectuer (Zar 1984). Les distances quotidiennes minimales ont été comparées en considérant les valeurs moyennes par animal pour chacune des périodes étudiées afin d'accorder un poids équivalent à chaque individu. Pour les déplacements sur une base mensuelle, uniquement les distances quotidiennes calculées à partir de localisations espacées de moins de 30 jours ont été retenues, mais en regroupant les données des trois années puisqu'il n'y avait pas de différences annuelles significatives.

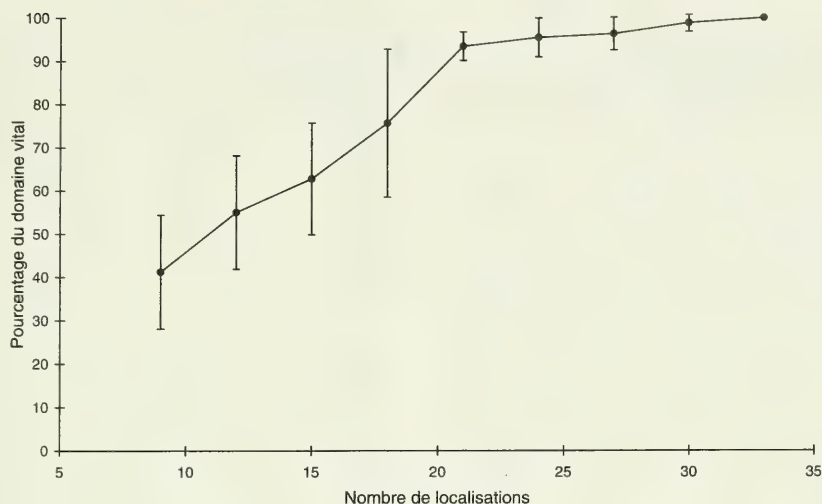


FIGURE 2. Pourcentage moyen (\pm écart type) de la superficie du domaine vital total estimée par la méthode du polygone convexe en fonction du nombre de localisations utilisées pour les 12 orignaux localisés 30 fois ou plus.

Résultats

Distances quotidiennes

Sur une base annuelle, la distance quotidienne moyenne (\pm erreur type) pour l'ensemble de la population a été de $0,22 \pm 0,02$ km/jour. Les moyennes furent de $0,29 \pm 0,06$ km/jour ($n = 19$) pour les juvéniles, $0,17 \pm 0,01$ ($n = 29$) pour les femelles et $0,22 \pm 0,03$ ($n = 16$) pour les mâles adultes. Les différences entre les groupes n'étaient pas significatives ($\chi^2 = 4,16$; $P = 0,125$) sur une base annuelle. Cependant, les femelles adultes se déplaçaient moins que les autres groupes à l'été ($\chi^2 = 3,96$; $P = 0,046$; Figure 3).

Les changements saisonniers au sein d'un même groupe ont été testés pour les orignaux dont les valeurs étaient disponibles pour les trois périodes. Les déplacements quotidiens d'automne et d'hiver différaient à la fois pour les juvéniles ($n = 13$; $\chi^2 = 9,02$; $P = 0,002$), les mâles adultes ($n = 15$; $\chi^2 = 4,95$; $P = 0,026$) et les femelles adultes ($n = 24$; $\chi^2 = 11,34$; $P < 0,001$). Chez ces dernières, une différence significative fut également détectée entre les déplacements quotidiens d'été et d'automne ($\chi^2 = 8,84$; $P = 0,003$). Les déplacements les plus importants furent notés en juillet chez les juvéniles ($0,52 \pm 0,37$; $n = 4$), en septembre et octobre chez les femelles adultes ($0,34 \pm 0,06$; $n = 59$ et $0,33 \pm 0,06$; $n = 29$) et en octobre pour les mâles adultes ($0,77 \pm 0,38$; $n = 11$).

Domaines vitaux

La superficie moyenne du domaine vital total a varié considérablement selon la méthode de calcul utilisée et ce, pour chaque groupe d'orignaux (Tableau 1). L'ellipse à 95% a donné les plus

grandes superficies moyennes, suivies des valeurs calculées par le polygone convexe. Les grands écarts entre les valeurs minimales et maximales indiquent une variabilité interindividuelle importante pour chaque groupe d'orignaux. Selon la méthode du polygone convexe, le domaine vital total était de 112, 131 et 66 km² pour les femelles adultes, les mâles adultes et les juvéniles respectivement. Chez les adultes, la superficie du domaine vital total ne différait pas entre les sexes pour aucune des sept méthodes de calcul utilisées ($\chi^2 \leq 2,46$; $P > 0,05$).

Chez les adultes également, la superficie du domaine vital d'été était de $53,3 \pm 10,2$ km² ($n = 23$) alors que l'estimation pour l'hiver fut de $36,1 \pm 9,4$ km² ($n = 18$). Lorsque les sexes étaient séparés (tableau 2), aucune différence significative n'a été notée entre les mâles et les femelles durant l'été ($\chi^2 = 0,71$; $P = 0,40$) ou l'hiver ($\chi^2 = 1,91$; $P = 0,16$). La taille des domaines vitaux n'a pu être comparée entre les sexes pour l'automne, aucune estimation valable n'étant disponible pour les mâles adultes durant cette période.

De façon générale, les domaines vitaux d'été, d'automne et d'hiver se chevauchaient partiellement. Chez l'ensemble des orignaux, $14,0 \pm 2,4$ % ($n = 32$) du domaine vital total était utilisé à la fois en hiver et durant le reste de l'année (mai-octobre). Les femelles et les mâles adultes affichaient des tendances similaires (chevauchement = $16,8 \pm 2,7$ %; $n = 32$) et différentes des juvéniles ($\chi^2 = 6,80$; $P < 0,01$); chez ces derniers, les domaines vitaux se chevauchaient peu entre les saisons ($4,1 \pm 1,5$ %; $n = 6$).

Discussion

Les déplacements et la superficie du domaine vital de l'orignal varient considérablement selon le sexe et l'âge des individus et selon la période de l'année. Dans l'est du Québec, la distance quotidienne moyenne parcourue par les femelles adultes était de 0,17 km/jour, ce qui est inférieur aux observations réalisées dans le sud-ouest du Québec (0,52 km/jour; Courtois et Crête 1988). Courtois et Crête (1988) expliquent les déplacements importants dans leur site d'étude par la présence de prédateurs et par la forte densité d'orignaux (3,7 orignaux/10 km²), cette dernière augmentant la fréquence des contacts entre les animaux. Or, le loup (*Canis lupus*), principal prédateur de l'orignal, est absent de l'est du Québec et les densités d'orignaux y sont faibles (1,0–1,2 orignal/10 km²), ce qui pourrait expliquer l'ampleur limitée des déplacements quotidiens.

Les informations disponibles dans la littérature concernant les déplacements et le domaine vital des juvéniles sont limitées et contradictoires. Habituellement, les juvéniles explorent et se dispersent davantage que les animaux plus âgés (Roussel et al. 1975; LeResche 1974; Lynch et Morgantini 1984). Les juvéniles marqués dans l'est du Québec se déplaçaient plus que les adultes, particulièrement durant l'été après la séparation de leur mère (Labonté et al. 1998), mais leurs domaines

vitaux n'étaient pas plus grands que ceux des adultes, une situation similaire à celle notée en Suède (Cederlund et Sand 1994) mais différente de celle observée en Alberta (Lynch et Morgantini 1984). La population que nous avons étudiée est caractérisée par une dispersion natale modérée soit en raison des faibles densités qui limitent les interactions entre individus ou soit, tel que noté en Suède, à cause d'un fort déséquilibre du rapport des sexes en faveur des femelles qui assure aux mâles un accès plus facile aux femelles (Labonté et al. 1998). Quant aux adultes, nos observations corroborent celles d'autres études (Goddard 1970; Sweanor et Sandegren 1989) qui concluent à une faible dispersion.

Dans le centre du Québec, les mâles adultes se déplaçaient plus que les femelles en été (juin à août) et à l'automne (septembre à novembre; Roussel et al. 1975). Un patron de déplacement semblable fut observé par Phillips et al. (1973) dans le nord-ouest du Minnesota, ce qui n'est que partiellement appuyé par nos observations, les déplacements ne différant que pour la période estivale dans notre cas. La plus grande sédentarité des femelles adultes en été est probablement due aux femelles suitées, qui se déplacent moins que les autres femelles (Courtois et Crête 1988), et qui sont nombreuses dans le cadre de cette étude (75 % des 21 femelles dont le statut reproduc-

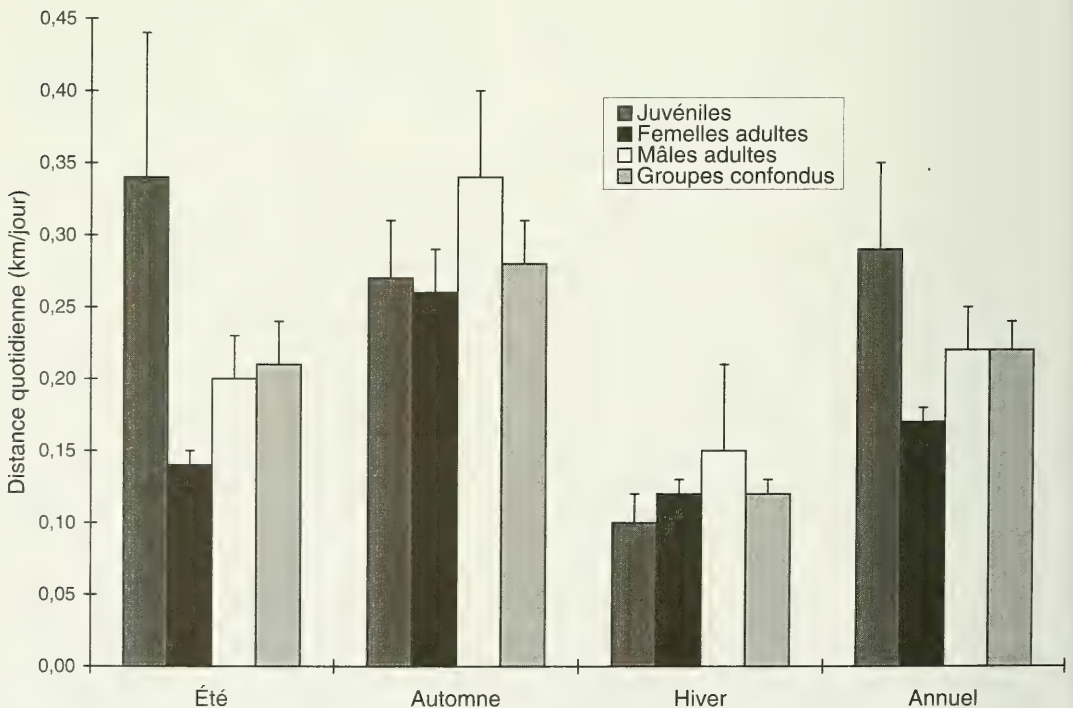


FIGURE 3. Distance moyenne des déplacements quotidiens (km/jour \pm erreur type) pour chaque groupe d'orignaux en fonction de la période.

TABLEAU 1. Superficie moyenne (km²) du domaine vital total selon différentes méthodes de calcul pour chaque groupe d'originaux de l'est du Québec.

	Polygone convexe	Polygone concave	Ellipse 95%	Moyenne harmonique			
				50%	70%	95%	100%
Femelles adultes							
Moyenne	112,3	27,0	273,5	11,0	22,9	85,6	132,7
Erreur type	29,0	5,4	77,8	2,6	5,8	20,1	31,3
minimum	7,5	3,9	19,7	0,7	1,3	4,65	7,0
maximum	522,6	131,4	1419,7	56,7	133,0	355,2	643,1
médiane	71,9	21,1	122,3	6,7	15,9	51,3	76,7
N	22	22	22	22	22	22	22
Mâles adultes							
Moyenne	131,0	22,3	431,7	10,9	30,6	74,6	139,0
Erreur type	49,4	7,2	188,2	4,4	15,0	26,7	47,3
minimum	6,9	2,9	20,9	0,3	1,2	3,6	4,6
maximum	542,2	64,8	2058,0	46,5	160,4	287,7	433,7
médiane	91,7	11,0	214,9	6,8	16,4	47,1	89,9
N	10	10	10	10	10	10	10
Juvéniles							
Moyenne	66,0	9,7	263,6	5,7	12,7	28,8	41,7
Erreur type	19,5	3,1	80,1	2,0	4,3	7,1	8,7
minimum	20,9	2,0	68,1	0,8	2,5	9,3	11,6
maximum	184,5	32,2	712,8	20,5	43,6	79,0	90,7
médiane	40,8	6,6	194,5	3,6	7,9	21,5	38,1
N	9	9	9	9	9	9	9

teur était connu) en raison d'une prédation plus faible due à l'absence du loup.

Les originaux de l'est du Québec ne migrent pas sur une base saisonnière. La distribution spatiale des localisations télémétriques de chaque original en fonction des périodes démontre en effet un chevauchement important des aires estivales, automnales et hivernales. Cela correspond aux observations faites sur une population de femelles adultes du sud-ouest du Québec (Courtois et Crête 1988). En Suède, le passage du domaine vital d'été à celui d'hiver se fait lorsque la neige atteint 40 cm, recouvrant de la sorte les arbustes nains composant la strate d'alimentation estivale (Sweanor et al. 1992). Dans l'est de l'Amérique du Nord, l'original s'alimente préférentiellement de ramilles d'arbres décidus (Crête 1989), lesquels sont assez uniformément distribués dans le milieu et demeurent accessibles même en présence de fortes accumulations de neige au sol. Le comportement migrateur est surtout avantageux dans des habitats contrastés, où la nourriture est distribuée inégalement (Cederlund et Okarma 1988). Un tel comportement migrateur est d'ailleurs fréquent en terrain montagneux, à la marge de la taïga et de la toundra (ex. Kufeld et Bowden 1996), ou dans les sites où l'original utilise surtout des saulaies en été (ex. Sweanor et al. 1992).

La superficie du domaine vital des originaux varie beaucoup d'un site d'étude à l'autre (Crête et Courtois 1997; Hundertmark 1998). En hiver, les femelles adultes de l'est du Québec (33,5 km²) ont

des domaines vitaux similaires à ceux des originaux du sud-ouest (37,0 km²) pour des périodes similaires (septembre-avril; Courtois et Crête 1988). Cependant, le domaine vital d'été est plus grand dans l'est (51,3 contre 32,0 km²; Courtois et Crête 1988), engendrant une valeur totale plus grande. Nos estimations sont également beaucoup plus élevées qu'au Minnesota, en Suède, au Montana ou au Colorado (été: 7–15 km²; hiver: 5–12 km²; Van Ballenberghe et Peek 1971; Berg et Phillips 1972; LeResche 1974; Cederlund et Okarma 1988; Sweanor et al. 1992; Van Dyke et al. 1995; Kufeld et Bowden 1996). Les originaux semblent ajuster la superficie de leur domaine vital en fonction des ressources disponibles (Lynch et Morgantini 1984; Cederlund et Sand 1994; Crête et Courtois 1997). Ainsi, il est possible que l'utilisation intensive des marais, des rives et des lacs pour l'alimentation estivale au Minnesota permet de limiter l'ampleur des déplacements (Roussel et al. 1975). De tels milieux sont rares dans nos sites d'étude, obligeant probablement les originaux à exploiter un domaine vital de taille plus importante pour répondre à certains de leurs besoins alimentaires. Une telle situation a d'ailleurs été rapportée au Maine (Leptich et Gilbert 1989). Une étude réalisée dans le centre-nord de l'Alberta entre 1971 et 1979 (Lynch et Morgantini 1984) rapporte des superficies de domaines vitaux comparables aux nôtres.

Les données publiées montrent généralement des domaines vitaux de faible superficie lorsque les den-

TABLEAU 2. Superficie moyenne (km²) du domaine vital selon la méthode du polygone convexe, en fonction de la période pour les mâles et les femelles adultes de l'est du Québec.

Sexe		Été	Automne	Hiver
Femelles	Moyenne	51,3	19,2	29,5
	Erreur type	12,5	3,5	8,8
	minimum	3,4	4,8	1,5
	maximum	179,7	34,5	135,9
	N	17	8	14
Mâles	Moyenne	59,1	-	59,3
	Erreur type	17,8	-	29,2
	minimum	3,7	-	8,1
	maximum	128,2	-	143,3
	N	6	0	4

sités sont élevées (ex. Suède: Cederlund et Okarma 1988; Sweanor et al. 1992; Cederlund et Sand 1994) et un accroissement des superficies couvertes en densité faible (Lynch et Morgantini 1984; Crête et Courtois 1997), suggérant un rôle important des interactions sociales. Les fréquentes agressions entre individus en très fortes densités (Sweanor et al. 1992) semblent conduire à une réduction de la superficie des domaines vitaux. Les faibles densités notées dans notre site d'étude s'ajouteraient aux effets de l'habitat pour permettre l'utilisation de grands domaines vitaux totaux.

Le domaine vital durant le rut semble varier avec le rapport des sexes et la densité de population (LeResche 1974). À cette période, les mâles adultes se déplaceraient de façon erratique à la recherche de femelles, accroissant ainsi la taille de leur domaine vital et l'amplitude de leurs déplacements (Lynch et Morgantini 1984; Knowlton 1960; Houston 1968; Berg 1971; LeResche 1974; Garner et Porter 1990). Selon Phillips et al. (1973), les femelles adopteraient un comportement opposé, se sédentarisant davantage durant le rut. Aucune estimation n'a pu être faite pour le domaine vital automnal des mâles adultes dans notre cas, mais on peut croire qu'il occupe une superficie importante à la lumière des grands déplacements quotidiens effectués pendant cette période. Par contre, les femelles adultes de notre site d'étude accroissent leurs déplacements durant le rut et deux femelles sur huit ont de plus augmenté la superficie de leur domaine vital. Claveau et Courtois (1992) ont aussi observé un comportement exploratoire évident chez les femelles de l'est du Québec durant le rut. Une situation semblable prévaut dans la forêt boréale du nord-est du Québec (Courtois et al. 1993). L'augmentation des déplacements pourrait être liée aux faibles densités qui obligent à une recherche plus intensive des partenaires sexuels (Sigouin et al. 1995). Pourtant, dans le site d'étude de Claveau et Courtois (1992), les densités d'originaux sont très élevées, de l'ordre de 20 individus/10 km², ce qui porte à croire que l'augmenta-

tion des déplacements en automne pourrait être liée à d'autres paramètres que les densités d'originaux. Dans l'est du Québec, la chasse intensive a non seulement entraîné une baisse des densités mais aussi un déséquilibre important du rapport des sexes en faveur des femelles chez les adultes (49 mâles/100 femelles; Courtois et Crête 1993). L'impact de ce déséquilibre est mal connu, mais il pourrait influencer le comportement exploratoire des femelles durant le rut tel que proposé par LeResche (1974).

Conclusion

La population d'originaux de l'est du Québec se caractérise d'abord par de faibles déplacements quotidiens. L'absence du loup et un stress social réduit en raison des faibles densités d'originaux pourraient expliquer ce résultat. La faible densité, combinée à la rareté des plans d'eau, pourrait expliquer une deuxième caractéristique importante de la population, soit la tendance à occuper des domaines vitaux de grande superficie, particulièrement à l'été. De plus, nous avons noté une augmentation des déplacements des femelles adultes à l'automne malgré leur confinement à un domaine vital généralement plus petit que durant les autres périodes. Ce comportement, sans doute lié à la recherche de partenaires sexuels pendant le rut, et détecté dans d'autres régions du Québec, diffère des données généralement rapportées dans la littérature (Goddard 1970; Phillips et al. 1973; Roussel et al. 1975; Cederlund et Okarma 1988). Crête et al. (1981) ont suggéré de maintenir 40% de mâles chez les adultes pour s'assurer que toutes les femelles puissent s'accoupler. Nous émettons l'hypothèse que le déséquilibre du rapport des sexes (32% de mâles chez les adultes) causé par une chasse intensive pourrait accroître le comportement exploratoire des femelles. Notre étude met en évidence la nécessité de mieux connaître l'impact de l'habitat, de la densité, de la structure des populations et de l'interaction de ces facteurs sur les stratégies d'utilisation de l'espace chez l'original.

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Farmland Habitat Use by Breeding Birds in Southern Québec

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Recent changes in agriculture in eastern Canada has resulted in changes in farming techniques and loss of farmland habitats which can have adverse effects on birds. Our knowledge of farmland bird communities in southern Québec is rather incomplete. Twenty-minute surveys were used to study farmland habitat use by 28 species of farmland birds in the St. Lawrence Lowlands of southern Québec in June 1992. European Starling (*Sturnus vulgaris*) was the species detected in largest numbers followed by House Sparrow (*Passer domesticus*), Red-winged Blackbird (*Agelaius phoeniceus*), Common Grackle (*Quiscalus quiscula*) and Barn Swallow (*Hirundo rustica*). Vesper Sparrow (*Pooecetes gramineus*), Upland Sandpiper (*Bartramia longicauda*), American Kestrel (*Falco sparverius*) and Northern Oriole (*Icterus galbula*) were the least detected species. Pastures, old fields and hayfields supported the highest bird abundances whereas figures were lowest in cornfields. Species richness was highest in old fields and pastures and lowest in urban areas and monocultures (corn, soybeans). Several species (House Sparrow, European Starling, Barn Swallow, Common Grackle, Tree Swallow [*Tachycineta bicolor*]) were mainly observed on and around houses and farm dwellings. Species abundance and richness would be higher on dairy farms than on farms with cash crops because of the reduced vegetation cover and intensive farming practices in cash crop fields.

Key Words: farmland birds, hayfield, pasture, cornfield, bird abundance, species richness, farming practices.

Farming brought tremendous changes to the original forested landscape and new habitats have been created. Several bird species have acclimated to these newly created ecosystems; others, however, have vanished from the original regions or became concentrated in remnant habitats such as farm woodlots. Recent changes in crops grown and farming techniques have resulted in loss of habitats on the margins of cultivated areas, and an increase in chemical use (pesticides, fertilizers) which can have adverse effects on birds (O'Connor and Shrubbs 1986; Freemark and Boutin 1995). For example, bird density and species richness in tilled fields are reduced compared to no-tilled fields (Basore et al. 1986), confirming that farmland birds may suffer from intensive agriculture. Therefore, attention has been given recently to documentation of changes in farming practices and their possible effects on bird communities in agricultural landscapes in North America (Graber and Graber 1963; Askins 1993; Rodenhouse et al. 1995; Jobin et al. 1996a) and in Europe (Solonen 1985; Diaz and Telleria 1994).

Although numerous studies have been conducted in North America on bird use of agricultural habitats (see Freemark et al. 1991; Rodenhouse et al. 1995), existing data have come mostly from single-species oriented studies (e.g., Rodenhouse and Best 1983), from species use of farmland and associated non-crop habitats such as shelterbelts and edges (e.g.,

Yahner 1983; Best et al. 1990; Choinière and Bélanger 1996) or from studies designed to evaluate crop damage by birds (e.g., White et al. 1985). In eastern Canada, our knowledge of farmland bird communities is rather incomplete and relies only on a few studies conducted in Ontario (Speirs and Orenstein 1967; Rogers and Freemark 1991; Boutin et al. 1996) and in Québec (McNeil et al. 1976; Potvin et al. 1976; Falardeau and DesGranges 1991; Jobin et al. 1994, 1996a).

Given that farmland bird populations can be affected by the recent changes in agriculture observed in eastern Canada (Jobin et al. 1996a), the objective of our study was to evaluate farmland habitat use by breeding birds in the St. Lawrence Lowlands of southern Québec. Species under study were limited to the 28 species most closely associated with farmland habitats in Québec as described by Falardeau and DesGranges (1991).

Study Area and Methods

The present study was part of a broader project undertaken using Breeding Bird Survey (BBS) data to assess trends of bird populations associated with agricultural practices and rural landscape changes over the past 25 years on selected BBS stops (Jobin et al. 1994). The BBS consists of annual surveys of breeding birds along roads in North America. Each route is divided into 50 stops spaced 800 m apart and

is surveyed once a year during the peak of the breeding season (Robbins et al. 1986). Our choice of sites was first confined to selected BBS routes. Out of the 92 routes distributed in the St. Lawrence Lowlands, we selected those (1) which have been surveyed at least 15 times between 1966 and 1990 and (2) where over 50% of the land surrounding the routes was dominated by cropland (cultivated fields, pastureland). Seven routes met these criteria.

The selected routes were located south of the St. Lawrence River between Montréal and Québec City, Québec, Canada, except for the Eardley route (45.5°N, 76.5°W), which was north of the Ottawa River in the Ottawa-Hull region. Large-scale cash crop production such as corn, barley and soybeans, dominated the two routes in southwestern Québec (Verchères [45.9°N, 73.3°W], Lacolle [45.2°N, 73.2°W]) with few crops associated with dairy farms. However, dairy farming and hog raising, and the accompanying pastureland and forage crops (hay, alfalfa) are more prevalent along the routes in the northeastern part of the St. Lawrence Lowlands (St. Célestin [46.3°N, 72.5°W], Ham Sud [45.8°N, 71.8°W], St. Antoine [46.8°N, 71.5°W], Ste. Marguerite [46.7°N, 71.0°W]) and along the Eardley route. Old fields and deciduous woodlands were generally more extensive on routes where dairy farms were numerous, resulting in a more diverse rural landscape along those routes. A detailed description of the individual routes can be found in Jobin et al. (1994, 1996b).

Because we were mainly interested in habitat use of typical farmland birds, we then selected BBS stops (along the seven routes retained) that met at least one of the following criteria: (1) more than 90% of the stop covered with cropland or (2) more than 50% of the stop covered with cropland with at least two other habitats present, including old field, deciduous woodland, urban area, and other habitats (coniferous woodland, open water, marsh, gravel pit, plantation, or clear-cut). The stops, each of a 400-m radius, were plotted on recent 1:20 000-scale forest maps and the various habitats present were identified. Of the 148 stops that met these criteria, the 82 selected stops were those where a vegetation survey had been carried out in the course of a concurrent study (Jobin et al. 1996b) and for which a questionnaire had been received from local farmers to obtain information on the farming practices and crops grown at the sites.

Cash crops covered 33% (corn: 17%, barley: 9%, oat: 6%, soybean: 1%) of the total coverage of all 82 BBS stops, dairy farming covered 44% (hay: 28%, pasture: 13%, alfalfa: 3%), and non-crop habitats covered 23% (old field: 7%, deciduous forest: 5%, urban area: 3%, other habitats: 8%). Herbicide use (mostly atrazine, metolachlor, glyphosate, MCPA, MCPB, 2,4-DB) was common in cash crop fields

whereas few herbicides were sprayed in forage crops (Jobin et al. 1997a).

Farmland habitat use by birds was determined by conducting a 20-min bird survey at each of the 82 selected stops. The observer walked the diameter of each stop along the road, counted the individuals of all species seen or heard, and noted the behavior of the observed individuals (feeding, singing, preening, moving, resting, territorial defense). Birds flying high over fields were not counted. Bird locations were noted on a detailed map of the stop showing habitats described in the forest map interpretation stage. In addition to crop use, bird use of houses and farm buildings was noted separately. Conducting these surveys at the same sites as those used for the BBS allowed us to compare our results to those of the BBS (Jobin et al. 1997b). Surveys were conducted between 2 and 16 June 1992 (the period of maximum breeding activity of most farmland species in southern Québec) from 05:00 to 10:30 hours (EDT) under good weather conditions (calm wind, no rain). Visits to the 82 stops were made in August 1992 to determine the actual acreage of each crop. Acreages were calculated using a Placom KP-90N digital planimeter. We determined bird abundance (number of individuals/10 ha) of each bird species in each habitat by superimposing data of bird surveys and habitat data. Because data lacked normality (even after being log-transformed), we used the nonparametric Kruskal-Wallis test (Zar 1984) to compare bird abundance and species richness among habitats. The nonparametric Q test for multiple comparisons of means (Zar 1984 : 200) was used to determine differences among groups.

Results

Species abundance

A total of 5803 individuals of the 28 farmland bird species under study was detected at the 82 stops. The European Starling (*Sturnus vulgaris*) was found in greatest numbers (overall mean of 15 individuals per stop), contributing to more than 21% of all birds noted during the surveys. Next in importance were the House Sparrow (*Passer domesticus*) (10.3%), Red-winged Blackbird (*Agelaius phoeniceus*) (9.6%), Common Grackle (*Quiscalus quiscula*) (6.6%) and Barn Swallow (*Hirundo rustica*) (5.6%). Eleven species had less than one individual on average per stop, with the Vesper Sparrow (*Poocetes gramineus*), Upland Sandpiper (*Bartramia longicauda*), American Kestrel (*Falco sparverius*) and Northern Oriole (*Icterus galbula*) being the least detected. Only seven species were observed on more than 75% of all stops. Although our study concentrated on farmland birds, all birds detected during the surveys were recorded which accounted for 6111 individuals representing 77 species. Most additional species were forest birds, the most abundant ones

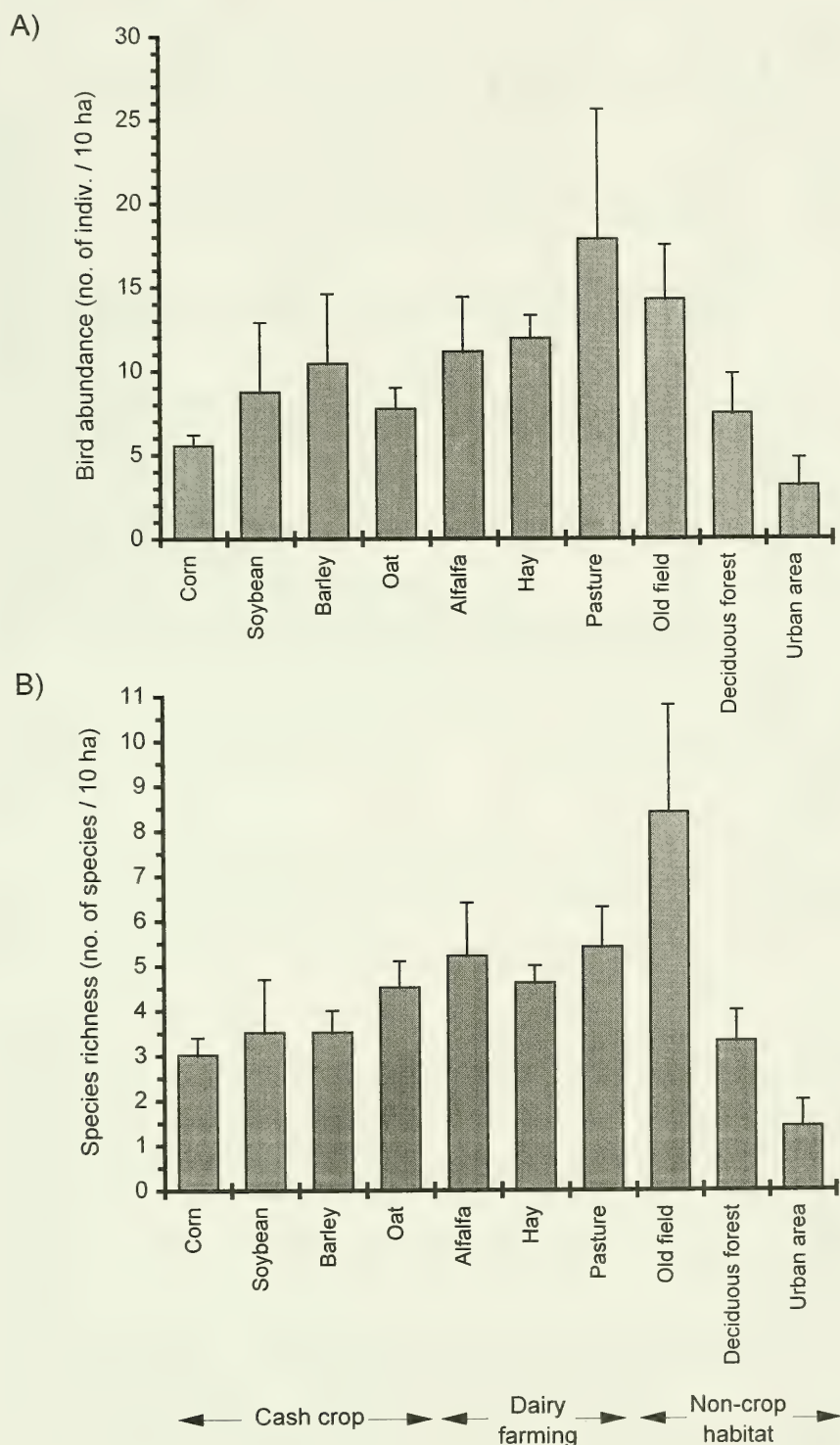


FIGURE 1. (A) Bird abundance (number of individuals / 10 ha \pm 1 standard error) and (B) species richness (number of species / 10 ha \pm 1 standard error) of the 28 species of farmland birds observed in farmland habitats found on the 82 BBS stops (note: means are calculated when the habitat was present only).

TABLE 1. Bird abundance (number of individuals/10 ha; standard error in brackets) and constancy (% of stops where species was detected) of 28 farmland bird species in crops and other habitats found on 82 selected BBS stops along 7 routes in southern Québec, June 1992.

Species	Cash crop (n=68) ^a	Dairy farming (n=77)	Old field (n=52)	Deciduous forest (n=42)	Urban area (n=22)	Constancy (%)
American Kestrel (n=9) ^b	0.00 (0.00)	0.05 (0.04)	0.25 (0.23)	0.02 (0.02)	0.00 (0.00)	9.8
Killdeer (n=74)	0.25 (0.07)	0.20 (0.04)	0.47 (0.26)	0.00 (0.00)	0.00 (0.00)	58.5
Upland Sandpiper (n=5)	0.01 (0.01)	0.01 (0.01)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	4.9
Ring-billed Gull (n=272)	0.59 (0.21)	0.66 (0.25)	0.17 (0.17)	2.94 (2.33)	0.00 (0.00)	32.9
Rock Dove (n=138)	0.40 (0.21)	0.30 (0.15)	0.02 (0.02)	0.00 (0.00)	0.00 (0.00)	42.7
Mourning Dove (n=46)	0.20 (0.12)	0.10 (0.04)	0.07 (0.07)	0.07 (0.06)	0.12 (0.09)	32.9
Eastern Kingbird (n=62)	0.15 (0.06)	0.19 (0.03)	0.35 (0.12)	0.06 (0.05)	0.02 (0.02)	56.1
Horned Lark (n=67)	0.23 (0.05)	0.13 (0.03)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	40.2
Tree Swallow (n=98)	0.23 (0.08)	0.21 (0.05)	0.16 (0.10)	0.00 (0.00)	0.23 (0.16)	54.9
Bank Swallow (n=126)	0.01 (0.01)	0.35 (0.20)	0.14 (0.14)	0.00 (0.00)	0.00 (0.00)	11.0
Cliff Swallow (n=42)	0.07 (0.06)	0.14 (0.08)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	9.8
Barn Swallow (n=127)	0.47 (0.16)	0.28 (0.07)	0.02 (0.02)	0.00 (0.00)	0.12 (0.12)	63.4
American Crow (n=94)	0.42 (0.21)	0.16 (0.04)	0.13 (0.07)	1.37 (0.68)	0.00 (0.00)	50.0
American Robin (n=138)	0.30 (0.11)	0.41 (0.09)	1.88 (1.23)	1.14 (0.45)	0.48 (0.33)	80.5
European Starling (n=340)	0.32 (0.09)	1.26 (0.34)	2.58 (1.89)	0.23 (0.17)	0.59 (0.44)	90.2
Yellow Warbler (n=82)	0.16 (0.06)	0.15 (0.04)	1.19 (0.35)	0.17 (0.08)	0.14 (0.10)	52.4
Chipping Sparrow (n=25)	0.01 (0.01)	0.06 (0.04)	0.11 (0.08)	0.07 (0.05)	0.24 (0.17)	20.7
Vesper Sparrow (n=2)	< 0.01 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	2.4
Savannah Sparrow (n=233)	0.49 (0.08)	0.86 (0.13)	0.41 (0.25)	0.00 (0.00)	0.19 (0.19)	82.9
Song Sparrow (n=246)	0.47 (0.07)	0.62 (0.10)	2.49 (1.23)	0.36 (0.18)	0.18 (0.10)	93.9
Bobolink (n=267)	0.23 (0.05)	1.35 (0.28)	0.17 (0.09)	0.00 (0.00)	0.00 (0.00)	79.3
Red-winged Blackbird (n=548)	1.01 (0.18)	1.80 (0.21)	2.28 (0.72)	0.39 (0.15)	0.06 (0.06)	98.8
Eastern Meadowlark (n=51)	0.07 (0.03)	0.18 (0.03)	0.09 (0.07)	0.00 (0.00)	0.00 (0.00)	37.8
Common Grackle (n=162)	0.49 (0.13)	0.28 (0.07)	0.85 (0.48)	0.00 (0.00)	0.16 (0.16)	76.8
Brown-headed Cowbird (n=56)	0.04 (0.02)	0.24 (0.07)	0.22 (0.11)	0.24 (0.16)	0.10 (0.07)	41.5
Northern Oriole (n=14)	0.02 (0.01)	0.03 (0.02)	0.00 (0.00)	0.08 (0.06)	0.00 (0.00)	13.4
American Goldfinch (n=178)	0.15 (0.04)	0.81 (0.34)	0.16 (0.10)	0.26 (0.13)	0.02 (0.02)	59.8
House Sparrow (n=63)	0.02 (0.01)	0.11 (0.06)	0.03 (0.03)	0.04 (0.04)	0.49 (0.45)	61.0

^aNumber of stops (out of 82) containing the habitat.

^bNumber in brackets is the total number of individuals surveyed in all habitats excluding houses and farm dwellings.

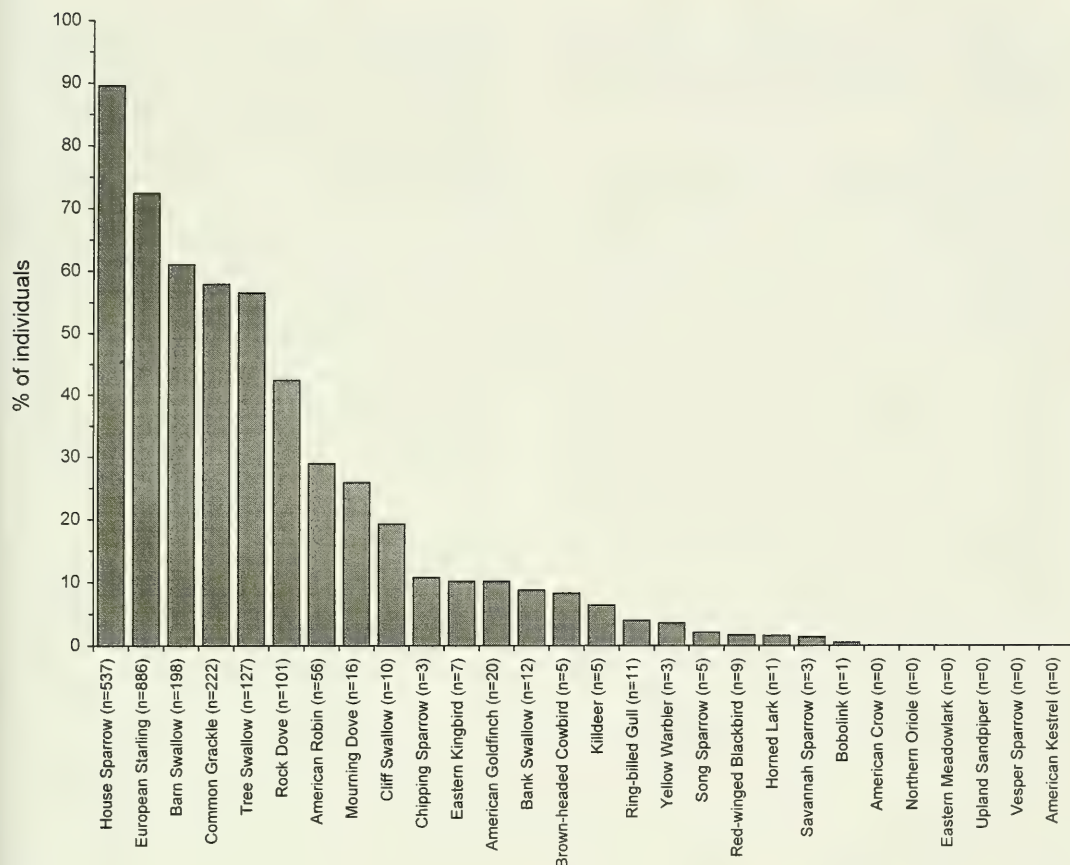


FIGURE 2. Percentage of individuals of the 28 species of farmland birds observed on and around houses and farm dwellings on the 82 BBS stops in June 1992 (note: the number following each species name is the number of individuals observed on the structures).

being the Common Yellowthroat (*Geothlypis trichas*), Cedar Waxwing (*Bombycilla cedrorum*), Red-eyed Vireo (*Vireo olivaceus*), and Alder Flycatcher (*Empidonax alnorum*). The list of all species observed and of their use of agricultural landscapes in southern Québec is found in Jobin et al. (1996a).

Although most birds observed were territorial males or pairs, some species were seen in flocks (> 2 individuals). Mean flock size of Bank Swallow (*Riparia riparia*) was 13.4 individuals (max = 50, n = 10) and flock size of Ring-billed Gull (*Larus delawarensis*) was 10.3 (max = 25, n = 25). Such aggregation was also common in the Rock Dove (*Columba livia*) (mean = 9.6, max = 25, n = 21), European Starling (mean = 7.7, max = 30, n = 148), American Goldfinch (*Carduelis tristis*) (mean = 7.4, max = 30, n = 18), House Sparrow (mean = 6.8, max = 30, n = 77), Cliff Swallow (*Hirundo pyrrhonota*) (mean = 6.4, max = 10, n = 7), and Barn Swallow (mean = 5.8, max = 14, n = 46).

Farmland habitat selection

Pastures supported the highest bird abundance (Kruskal-Wallis: $\chi^2 = 49.8$, df = 9, $P < 0.0001$) of all habitats found on the selected BBS stops followed by old fields and hayfields (Figure 1A). Bird abundance was low in cornfields although acreage under this type of crop was high in several routes. Urban areas showed the lowest bird abundance of all habitats (0.31 ind./ha). Multiple comparisons revealed that bird abundance was higher ($P < 0.05$) in hayfields and pastures than in deciduous woodlands and in urban areas. In addition, figures were higher in old fields than in urban areas; and higher in hayfields than in cornfields. Species richness (number of species per habitat) was highest in old fields (Kruskal-Wallis: $\chi^2 = 38.3$, df = 9, $P < 0.0001$) followed by pastures and alfalfa fields (Figure 1B). Species richness was lowest in urban areas which were rarely present in our study plots. Multiple comparisons revealed that species richness was higher ($P < 0.05$) in hayfields, pastures, oatfields and old

fields than in urban areas. Farmland bird abundance and species richness were therefore higher in areas dominated by dairy farming (pastureland, hayfields, alfalfa) compared to large size monocultures (corn, soybeans).

We calculated abundance of each species in crops and other habitats found in our study plots. However, old fields, deciduous forests and urban areas each covered less than 10% of the total area surveyed which greatly limited the statistical analysis of habitat selection by farmland species (Neu et al. 1974). Although not supported by statistical evidence, habitat selection was manifest for many of them and revealed that crop use by farmland birds differed among species. Cash crops (corn, soybeans, oats, barley) form uniform habitats where plant species diversity is generally confined to a single dominant species; i.e., the crop itself. Nevertheless, some species frequent this type of habitat in preference to other habitats, examples include the Barn Swallow, Rock Dove, Horned Lark (*Eremophila alpestris*), and Mourning Dove (*Zenaidura macroura*) (Table 1). Species showing their highest abundance in crops associated with dairy farming operations (alfalfa, hay, pastures) were the Bobolink (*Dolichonyx oryzivorus*), Savannah Sparrow (*Passerculus sandwichensis*), American Goldfinch, Eastern Meadowlark (*Sturnella magna*), Bank Swallow, and Cliff Swallow.

Abandoned fields which have reverted to scrub or forest land are highly used by some passerine species either for nesting or feeding. Abundance of the Song Sparrow (*Melospiza melodia*), European Starling, Yellow Warbler (*Dendroica petechia*), Common Grackle, Red-winged Blackbird, Eastern Kingbird (*Tyrannus tyrannus*), Killdeer (*Charadrius vociferus*), and American Robin (*Turdus migratorius*) were highest in old fields, whereas late successional stages such as deciduous forests and forest edges were particularly frequented by the American Crow (*Corvus brachyrhynchos*), American Robin, and Northern Oriole. High abundance of Ring-billed Gulls in deciduous forests is a spurious observation and relates to the presence of a group of individuals observed along a forest edge. Finally, the most disturbed habitats of all, urban areas, housed several species showing abundances higher than in crop fields. This was the case for the House Sparrow, Tree Swallow (*Tachycineta bicolor*), and Chipping Sparrow (*Spizella passerina*). We also examined bird use of houses and farm dwellings compared to other habitats. Several species typically associated with the rural landscape and urban areas were mainly observed outside crop fields on and around these structures (Figure 2). More than 50% of all House Sparrows, European Starlings, Barn Swallows, Common Grackles, and Tree Swallows observed were seen on and around farm buildings and houses.

Observation of feeding individuals (or groups) was common for several of the farmland species under study. Feeding habitat preferences were determined for only a few species, however, because of inadequate sample sizes for most species. Most (> 50%) American Crows ($n = 39$ individuals or groups), Rock Doves ($n = 65$) and Common Grackles ($n = 42$) were observed feeding in cash crops (corn, barley, oats, soybeans) although vegetation diversity is greatly reduced in these fields whereas Red-winged Blackbirds ($n = 38$), European Starlings ($n = 199$) and Ring-billed Gulls ($n = 112$) preferably used hayfields and pastures for feeding. Brown-headed Cowbirds (*Molothrus ater*) were generally observed feeding in pastures (71% of 14 observations), and several groups of Bank Swallows and Ring-billed Gulls were seen foraging in open water areas.

Discussion

During our surveys in June, cash crop fields which are ploughed annually are devoid of a herbaceous layer, the only vegetation being the crop, itself, then only a few centimetres high. Herbicide use and tillage in intensive agriculture reduces vegetation diversity and cover in fields and adjacent habitats (Chancellor 1979; Jobin et al. 1997a) which lowers cash crop value as wildlife habitats because of reduced protection against predators and reduced food availability such as insects. Bird diversity and abundance may be directly affected by these practices (Solonen 1985). On the other hand, fields associated with dairy farming activities (hay, pastures, alfalfa) presented a well-developed herbaceous layer for arriving spring migrants. Pastures and hayfields resemble natural habitats such as prairies whereas tilled fields have no natural-habitat counterpart, so few species are adapted to utilize them. This could explain why bird abundance and species richness were higher on dairy farms than on farms with cash crops (Jobin et al. 1996a). In addition, insecticide-treated seeds and granular insecticides are commonly used in cash crops but not in hayfields and pastures. These farming practices may be detrimental to birds resulting in a possible avoidance of fields where these practices occur (Rodenhouse et al. 1995).

Many studies also revealed that bird use of crop fields was more intense at the perimeter of the fields and in hedgerows and woodland edges, than at the center of the field (Best et al. 1990; Boutin et al. 1996; Choinière and Bélanger 1996). In our study sites, cash crop fields, hayfields and pastures were bordered by the same proportion of hedgerows, old fields, and deciduous woodlands (length of border/ha of field type; Kruskal-Wallis test comparing field types; $P > 0.05$). Differences observed in bird abundance and species richness among fields would not therefore be related to the immediate landscape

where fields were located but most likely reflected actual differences in field type.

Nevertheless, our results showed that some species had their highest abundance in cash crops. This was the case for the Horned Lark and the Vesper Sparrow, known to nest in bareground fields (Graber and Graber 1963; Rodenhouse and Best 1983), and other species (e.g., Rock Dove, American Crow) feed in these habitats (Potvin et al. 1976). Species typically associated with dairy farms (Savannah Sparrow, Bobolink, Eastern Meadowlark, American Goldfinch, Upland Sandpiper) as described in earlier works (Graber and Graber 1963; Speirs and Orenstein 1967; Falardeau and DesGranges 1991; Best et al. 1995) were also observed in greater number in hayfields and pastureland than in other studied habitats. The review conducted by Freemark et al. (1991) on bird use of farmland habitats in the Great Lakes - St. Lawrence region revealed that species richness was higher in cornfield than in any other crop field. Studies included in their analysis however, were gathered from different sources aiming at various objectives. In several cases, few species were reported and season of use of crop field was lacking for several others. High species richness in cornfields might therefore only reflect the higher number of studies conducted in that type of crop compared to others. In general, our observations suggested that farmland habitat use by breeding birds follows the same pattern as observed in other studies conducted in Québec and in other regions of North America; i.e., Ontario, United States.

We also observed that several species preferentially use non-crop habitats; e.g., Song Sparrow, American Robin, Yellow Warbler and Common Grackle were most abundant in old fields, and the Northern Oriole and American Crow in deciduous forests and woodland edges. These species typically used these heterogeneous habitats either for nesting or feeding, or both (Graber and Graber 1963; Gauthier and Aubry 1996).

Bird use of farmland habitats can be markedly affected by human modifications of the rural landscape. For instance, Camp and Best (1993) showed that bird diversity and abundance was higher along roadsides than in rowcrop fields. In addition, farm buildings and urban areas in agricultural landscapes provide "unnatural" habitats to farmland birds which can take advantage of these structures; as it was shown for several species in our study. Species closely associated with these structures were generally sedentary cavity-nesters whose nesting season begins earlier than the other species; the latter being mostly ground-nesters (see Jobin et al. 1994). The abundances of the two species more closely associated with farm buildings on our study sites (House Sparrow and European Starling) were also correlated with the number of buildings in Yahner's (1983)

study in Minnesota. Avian diversity is, however, generally low in urban areas, species assemblage being dominated by only a few but abundant species (Bezzel 1985), most likely of introduced origin as reported by Erskine (1971) for surveys conducted in urban areas in Ontario.

Several species of farmland bird have shown declining populations over the past 25 years in southern Québec, the most noteworthy being the Vesper Sparrow, Savannah Sparrow, Bobolink, Killdeer, Brown-headed Cowbird and Eastern Meadowlark (Cyr and Larivée 1995). The decline of several of these species has also been observed in other regions of North America (Askins 1993). Jobin et al. (1996a) argue that this decline could be related to the disappearance of dairy farms that are being converted to intensive monocultures in the southwestern part of Québec, or to softwood plantations (mostly Christmas trees) and old fields in the eastern part of the St. Lawrence Lowlands (Domon 1994). Because the area occupied by hayfields and pasturelands still continues to decrease in southern Québec (Statistics Canada 1992), we need to better understand avian population dynamics in agricultural landscapes in order to harmonize new farming practices with the preservation of avian biodiversity in agricultural landscapes. Large-scale studies of bird use of agricultural habitats in the St. Lawrence Lowlands should therefore be encouraged.

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Municipal Landfill Impacts on a Natural Stream Located in an Urban Wetland in Regional Niagara, Ontario

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Dickman, M., and G. Rygiel. 1998. Municipal landfill impacts on a natural stream located in an urban wetland in Regional Niagara, Ontario. *Canadian Field-Naturalist* 112(4): 619–630.

In 1989, the 400 km long Niagara Escarpment was designated an Ecological Biosphere Preserve Area by UNESCO. Landfills on top of the escarpment were the subject of study in terms of their potential impacts on the streams and forest vegetation on the escarpment slopes below. Surprisingly little has been published on the impacts of these landfills on urban streams and wetlands. In the present study, a forested hillside stream (Leawood Creek) was chosen because its headwaters were located immediately below a municipal landfill which is perched on the brow of the Niagara Escarpment. High iron and zinc concentrations in the study creek, compared to nearby unimpacted creeks, were interpreted as an indication that leachate from the Glenridge Landfill had previously contaminated Leawood Creek. Iron concentrations in the sediments of the study creek averaged 26 000 ppm and zinc reached a concentration of 310 ppm. Both zinc and iron are common constituents of the numerous metal objects deposited in the landfill. The Leawood Creek study stream flows at an average rate of 3.2 L sec⁻¹. Because the Creek is spring-fed, it flows continuously throughout the year. During the study period (January to June 1991), the biota in the lower portion of the creek differed substantially from the upper (escarpment) as did the iron bacterium (*Gallionella*) which was absent from the lower section of the creek. *Gallionella* discoloured the rocky substrate in the upper sections of the Creek near the landfill. Prior to the creation of the Glenridge Landfill in 1976, Leawood Creek contained numerous invertebrates including mayflies, amphipods (scuds), water pennies (Coleopterans), stoneflies and caddisflies. In 1991, after 15 years of operation, only snails, pollution tolerant blood worms (chironomids) and sludge worms (tubificids) were found in any abundance in this spring-fed creek. Thus, pollution-sensitive stream invertebrates such as scuds, mayflies and caddisflies have been replaced by pollution tolerant sludge worms, nematodes, snails and blood worms.

Key Words: Urban wetlands, urban landfills, pollution tolerant species, chironomids, iron bacteria, chemolithotrophs, leachate impacts, Ontario.

Urbanization and the construction of urban landfills go hand in hand in many communities throughout the world, but, surprisingly, little has been published on the impacts of these landfills on urban streams. For our study we selected a stream with its headwaters located near a municipal landfill which in turn is perched on the brow of the Niagara Escarpment.

The trickling seeps and springs along the Niagara Escarpment can harbour an unassuming but unique wildlife community. The Niagara Escarpment is one of the few places they are found in North America (Stabb 1991). In 1989, the 400 km long Niagara Escarpment was designated an ecological biosphere preserve area by UNESCO. The Niagara Escarpment Commission recently concluded that landfills constructed on escarpment lands threaten the natural biota of the Niagara Escarpment and placed a moratorium on the construction of any new Niagara Escarpment landfills.

Our purpose was to investigate the influence of water flowing from an urban landfill on the sediment chemistry and biotic community structure of a small forested creek in southern Ontario. Although the U. S. Environmental Protection Department (1986) has reported that the majority of the engineered land-

fills that it has investigated ultimately leak, very little has been published on the impacts of these leaks on downslope vegetation and/or aquatic ecosystems impacted by the leachates. To address this point, a study was undertaken fifteen years after the creation of the engineered Glenridge Landfill.

Description of the Study Area

The Glenridge Engineered Landfill is composed of seven adjacent 1.4 m thick compacted clay pads which form the base of each "cell". It is located in a mined-out limestone quarry on the north side of St. David's Road West (Regional Road 71) and Glenridge Avenue (Regional Road 30) in the City of St. Catharines, Ontario (Figure 1). The landfill occupies 43.3 hectares (107 acres) and contained approximately 1.2 million tonnes of solid waste in 1992. The landfill began operation in 1976 and has an approved capacity of 2.2 million metric tonnes of waste. It receives the municipal wastes of the City of St. Catharines (1992 population of 124 000).

Leawood Creek has its headwaters just below the landfill. The upper reaches of the creek are surrounded by a maple, oak, ash and beech forest. Maple is the dominant tree. The trees comprise part of a typical temperate closed canopy eastern hardwood forest.

TABLE 1. Benthic macroinvertebrates and filamentous algae from stations 1-4 in Leawood Creek for the period 31 January to 18 February, 1991

Species Name	Station 1 (#/m ²)	Station 2 (#/m ²)	Station 3 (#/m ²)	Station 4 (#/m ²)
Benthic invertebrates				
Nematodes	10 000	6000	5000	4000
Insecta				
Chironomids	83	35	16	13
Coleopteran larvae		5	36	
Ceratopogonids (noseeums)	22	—	—	6
Crustaceans				
Isopoda (scuds)	—	—	3	5
Mollusca (snails)				
Planorbidae	6	10		4
Lymnaeidae	767	780	94	158
Oligochaetae	11	5	6	7
Benthic invertebrate remains				
Empty Chironomid cases	(6000)*	(6000)	(5000)	(3000)
Empty Trichopteran cases	(4000)	(900)	(2000)	(2000)
Mollusca (snails)				
Helisoma (empty shells)		—	(300)	
Lymnaea (empty shells)		—	(400)	

*numbers in parentheses represent estimates made from a single set of winter samples, all others are means for three replicate samples

Leawood Creek passes under Glenridge Avenue via a 76 cm (30 inch) corrugated pipe which discharges at an average rate of 3.2 litres per second as indicated by the time it took the water leaving the 76 cm corrugated pipe to fill a 50 litre carboy container on 40 occasions during the year. The creek descends through the Niagara Escarpment and then leaves the escarpment near its base to enter an underground pipe which re-emerges about 800 m downslope to flow toward and into 12 Mile Creek. The latter creek discharges into Lake Ontario near Port Dalhousie in St. Catharines, Ontario (upper inset, Figure 1). Four locations were chosen for study along the 110 m long escarpment stretch of the upper portions of Leawood Creek (Sites 1-4, Figure 1, lower inset). The lower portion of the Creek (the part below the 800 m long section of pipe) is referred to as the lower study area (Figure 1). This area was walked and sampled on a qualitative basis once each season in 1991. Distances were approximated by measuring the senior author's stride and multiplying by the number of steps taken.

In the early 1970s before the Glenridge Landfill was constructed, the escarpment section of Leawood Creek had a diverse assemblage of benthic invertebrates including crustaceans (primarily amphipods, Dickman 1991*). Although no quantitative benthic invertebrate analyses were carried out in these early years, a number of invertebrates were collected on a

qualitative basis. A variety of chironomids (midges), trichopterans (caddisflies), ephemeropterans (mayflies) aquatic snails (gastropods), coleopterans (including water pennies), nematodes (pin worms), oligochaetes (aquatic earthworms), isopods (pill bugs) and amphipods (scuds) were observed and collected from Leawood Creek prior to 1976. These results were similar to those described for other escarpment spring-fed creeks (Stabb 1991; Bird and Hale 1992*).

Materials and Methods

In 1991, 34 elements in the sediments of Leawood Creek were analyzed and their concentrations compared to natural background levels in a nearby intermittent creek which does not receive water from the landfill area (stream "X" on lower inset of Figure 1). Attached algal, bacterial and benthic invertebrate sampling was done at the same time that the water chemistry and sediment chemistry analyses were carried out.

To sample the invertebrates we used a small Ponar sampler which enclosed an area of 225 cm² (0.025 m²). During the winter sampling period, Ponar sediment samples were taken on 31 January, 5 February, and 18 February 1991. In addition, 15 sediment samples were taken on 12 February. All 15 of these sediment samples were sent to Becquerel Laboratories Ltd. [Unit 4, 6790 Kitimat Road, Mississauga, Ontario L5N 5L9, Canada; 1994] for analyses of 34 elements by neutron activation.

*See Documents Cited Section.

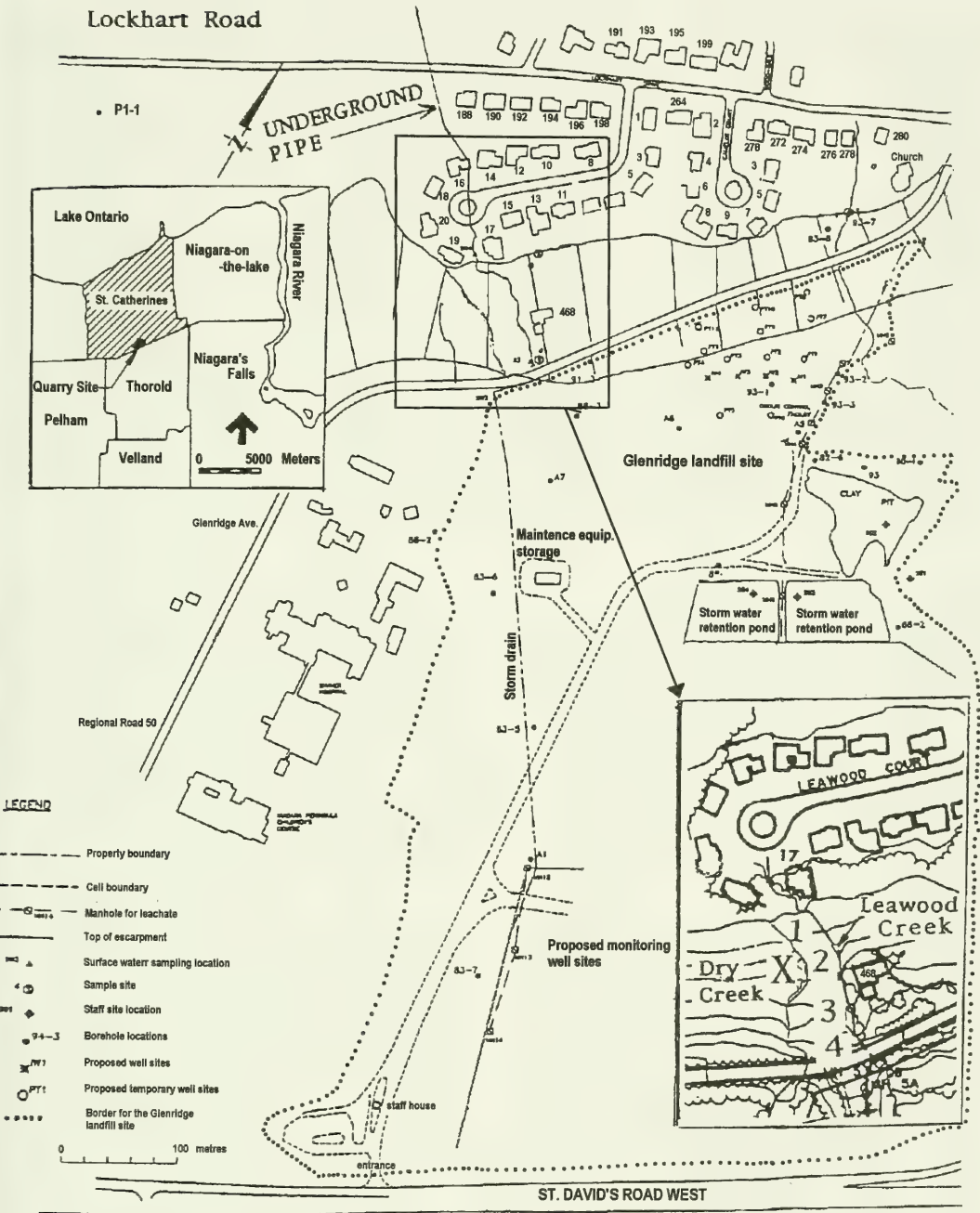


FIGURE 1. Glenridge Landfill located at the corner of St. David's Road (Regional Road 71) and Regional Road 30 (Glenridge Avenue). The two roads intersect where the metre scale in the legend at the lower left hand corner of the map is located. The two study creeks "X", the intermittently dry creek and Leawood Creek (Sites 1-4), are indicated on the inset in Figure 1 located at the end of the long chain of arrows. Leawood Creek enters an underground pipe at the side of house number 17 on Leawood Court (lower inset). The second (upper) inset with its 6 km scale is self explanatory. Samples taken south of Lockhart Road after the creek re-emerges from an underground pipe are termed the "lower study area". Maps are modified from those published by Gartner Lee (1991*).

TABLE 2. Filamentous algae from stations 1-4 in Leawood Creek

Cyanophyta*				
Genus Name	Station 1 (#/cm ²)	Station 2 (#/cm ²)	Station 3 (#/cm ²)	Station 4 (#/cm ²)
<i>Lyngbya</i>	5 500	5 000	4 000	5 000
<i>Oscillatoria</i>	9 000	8 000	6 000	7 000
<i>Phormidium</i>	200	300	300	400
<i>Rivularia</i>	6 000	2 000	4 000	2 000
Filamentous green algae (Chlorophyceae)*				
Genus Name	Station 1 (#/cm ²)	Station 2 (#/cm ²)	Station 3 (#/cm ²)	Station 4 (#/cm ²)
<i>Mougeotia</i>	0/10**	0/20	0/20	0/10
<i>Ulothrix</i>	0/20	0/35	0/30	0/25
<i>Cladophora</i>	0/800	0/900	0/1200	0/2100

*Older filaments were coated with a thin reddish brown layer, young filaments were without such coatings. *Cladophora* was densely colonized by epiphytic diatoms (e.g., *Gomphonema* sp.)

**0/10 indicates that 0 cells of *Mougeotia* per cm² were observed at this site in winter and 10 in spring. Winter samples were collected on 31 January and 18 February 1991, spring samples were collected on 21 May 1991 and summer samples were collected on 17 June 1991. Data from the summer samples are not presented in this paper because it was not known when the City of St. Catharines began adding chlorinated tap water to the stream.

Standard QA/QC procedures (Canter 1985) were followed. Twelve of the fifteen winter samples taken on 12 February were from Leawood Creek (three at each of the four sites indicated in Figure 1). The remaining three samples were taken from site "X" in a dry creek bed (lower inset, Figure 1) that was unimpacted by the landfill. The top of this dry creek was located near telephone pole #273 on Glenridge Avenue.

In winter, fifty-four Ponar samples were taken from Stations (sites) 1-4 for the purpose of collecting benthic invertebrates. Due to the low benthic invertebrate densities in winter, 10-15 Ponar samples were taken from each site (four trips to each of the four sites were needed to collect the 54 Ponar samples). Only in this way were we able to gather sufficient invertebrates to give quantitative estimates of their abundance during winter. In spring, samples were collected by taking four Ponar samples at each site. The summer and fall data are not presented because the City of St. Catharines began placing City tap water into Leawood Creek to replace the water it took from the creek's head waters for discharge to pipes leading to the City's sewage treatment facility making it impossible to distinguish between biotic effects associated with the residual chlorine in the tap water entering the creek's head waters and the effects of the contaminated groundwater.

The spring study of Leawood Creek started on 21 May 1991. Four Ponar dredge samples were collected from each of the four stations. Winter and Spring samples were sorted within three days of sampling. Invertebrate identifications were checked by Bill Morten. In order to identify the chironomids (midge larvae), each chironomid head capsule was separated from its body and soaked in 10% KOH solution. Normally a soaking period of fifteen hours was suffi-

cient time to allow most of the chitinous head capsule tissue to be cleared away from the mentum. In some cases the head capsules required further treatment. After 15 hours, the head capsules were removed from the KOH solution, rinsed, and mounted on glass slides.

The Shannon-Wiener index (H) (Peet 1974) was calculated for chironomids as $H = -\sum (p_i \log_2 p_i)$ where p_i represents the number of individuals in one genus divided by the total number of individuals in all genera in the sample. Diatom species richness and density were also calculated. Because only the chironomids and diatoms were identified to species or genus, diversity for the other taxa (which were identified to Family or Order etc.) was not calculated.

Algae, fungi and bacteria were estimated by scraping a known area (1 cm²) of hard packed mud or rock at each of the four sample sites. Enumeration was based on a minimum count of 600 cells per sample. Procedures for cleaning, mounting and counting the bacteria and algae are described in Dickman et al. (1984) and Dickman and Rao (1989). Literature used in the identification of the algae included Buchanan and Gibbons (1974), Camburn and Kingston (1985*), Cleve-Euler (1951-1955), Germain (1981), Prescott (1980) and Patrick and Reimer (1966, 1975). Isolation and propagation methods for *Gallionella* were based on the methods of Kucera and Wolfe (1957), Hanert (1981) and (Ehrlich 1990).

This study was terminated in the summer of 1991 when engineers from the City of St. Catharines diverted all the water entering the Creek to the City's sewage treatment facility and substituted dechlorinated City tap water for the original flow. Attempts to dechlorinate this tap water were not always met with success.

TABLE 3. Diatoms from stations 1-4 in Leawood Creek

Bacillariophyta (Diatoms)***				
Species Name	Station 1 (#/cm ²)	Station 2 (#/cm ²)	Station 3 (#/cm ²)	Station 4 (#/cm ²)
<i>Achnanthes lanceolata</i>	160/20*	220/0	50/0	60/0
<i>Asterionella formosa</i>	0/20	0/0	0/0	0/0
<i>Caloneis clevei</i>	0/190	0/150	0/300	0/130
<i>Caloneis</i> sp.	T/530**	0/180	0/510	T/200
<i>Cymbella hungarica</i>	20/90	30/80	40/20	30/40
<i>Entomoneis paludosa</i>	T/60	T/170	0/20	T/730
<i>Eunotia exigua</i>	0/400	0/810	0/900	0/0
<i>Fragilaria virescens</i>	T/760	T/810	0/200	T/1050
<i>F. virescens</i> var. <i>elliptica</i>	0/20	0/0	0/0	0/150
<i>F. virescens</i> var. <i>capitata</i>	0/0	0/130	0/10	0/20
<i>Frustulia vulgaris</i>	T/160	T/200	0/10	T/130
<i>Gomphonema constrictum</i>	T/260	T/220	0/10	T/130
<i>Gomphonema parvulum</i>	200/970	150/830	50/180	300/310
<i>Mastogloia smithii</i>	T/910	T/410	200/2440	100/1170
<i>Navicula dissipata</i>	T/80	T/300	0/0	0/20
<i>Navicula dubia</i>	500/80	450/50	230/110	500/510
<i>Nitzschia hantzschia</i>	T/300	T/120	100/690	T/270
<i>Nitzschia palea</i>	T/660	T/1300	T/600	100/1010
<i>Nitzschia pusilla</i>	T/220	100/430	0/100	0/70
<i>Pinnularia abaujensis</i>	50/0	20/0	10/30	40/50
<i>Rhoicosphenia curvata</i>	0/30	0/40	0/40	0/40
<i>Surirella ovata</i>	100/540	T/310	100/400	100/410
<i>S. ovata</i> var. <i>apiculata</i>	0/20	0/10	0/10	T/140
<i>Tabellaria fenestrata</i>	0/40	0/0	0/0	0/0
Diatom Species Richness	17/24***	15/20	9/21	15/21

*160/20 indicates that 160 diatoms per cm² were observed at this site in winter and 20 in spring. Winter samples were collected on 31 January and 18 February 1991, spring samples were collected on 21 May 1991 and summer samples were collected on 17 June 1991.

**T/530 indicates that only 1 or 2 individuals per slide (trace) were observed in winter and 530 diatoms per cm² were observed at this site in the spring. Data from the summer samples are not presented in this paper because it was not known when the City of St. Catharines began adding chlorinated tap water to the stream.

***17 species of diatom were observed at site 1 in winter and 24 species in summer.

Results

During the winter study period (31 January-18 February 1991), air temperatures varied between -6°C and +5°C but the water in Leawood Creek never completely froze, flowing at 1-20 litres per second. Each of the 54 Ponar samples taken during the winter (12-14 per site) was sorted by placing the contents of the Ponar on a large enamel pan and

TABLE 4. Microflagellates, fungi and filamentous bacteria from stations 1-4 in Leawood Creek, 31 January and 18 February, 1991

Microflagellates				
Name	Station 1 (#/cm ²)	Station 2 (#/cm ²)	Station 3 (#/cm ²)	Station 4 (#/cm ²)
Mastigophorans				
Taxa with chlorophyll	5000	4500	2300	5000
Colourless taxa	9000	8000	6000	7000
Fungi				
<i>Varicosporium</i>	+	+	+	+
<i>Ceriospora</i>		+	+	+
Filamentous iron Bacteria				
<i>Gallionella</i>	In winter, iron bacteria disappear in cold climates (Ghiorse 1984)			
<i>Leptothrix</i>	Rare			
<i>Beggiatoa</i>	A few filaments were identified by H. Ehrlich in February of 1991			

TABLE 5. Chironomid data for 76 individuals and 7 genera observed on 21 May 1991.

	Site 1	Site 2	Site 3	Site 4	Total
Generic Richness	5	4	4	1	7
Generic Diversity (H)	0.97	1.30	1.48	0	0.94

checking for any movement indicating the presence of invertebrates. Over 1000 microinvertebrates, primarily nematodes and microflagellates, were counted (Tables 1 and 2). Thirty-four chironomid larvae and 156 other macroinvertebrates were obtained from the winter Ponar samples (Tables 3 and 4).

As expected, the abundance and diversity of macroinvertebrates in spring was far greater than in winter. There were also 49 empty aquatic snail shells and a number of terrestrial invertebrates present in spring which were collected in the Ponar samples [earthworms (17), slugs (1), millipedes (2), terrestrial insect larvae (7)]. Chironomid generic richness (Table 5) and density (Table 6) are presented for the spring (21 May) sample period. The abundance of the eight most common invertebrate taxa (Table 7) are also presented for the spring sample period.

Sediment Chemistry

Of the sediment samples removed on 12 February, 1991, 12 were sent to Becquerel labs for Neutron activation analysis. Concentrations of the 34 elements found in the Creek's sediments are given in Table 6. Our ambient samples were based on samples taken from a nearby "control" or "reference" creek with its headwaters at Glenridge Ave. This creek is indicated by the "X" on the inset in Figure 1. Because Leawood Creek is the only spring fed creek with its headwaters near the Glenridge Landfill site the selection of a control or reference creek for comparison purposes was problematic. Bird and Hale (1992) choose the headwaters of 12

TABLE 6. Chironomid abundance and density at four sites for 21 May 1991.

	Site 1	Site 2	Site 3	Site 4	Total
Number of individuals	27	29	16	4	76
chironomid density (#/m ²)	300	430	178	44	952

Mile Creek as their reference site but the location was so distant from Leawood Creek (over 10 km) that we decided that the nearby intermittent creek was more appropriate.

Discussion

Contaminants Present in Leawood Creek

Iron, and zinc concentrations were substantially higher in the sediments of Leawood Creek (Table 8) than in the sediments of the nearby intermittent creek which was unimpacted by the landfill discharge (Table 9). These elevated metal concentrations were interpreted as indicative of both the direct and indirect effects of the nearby landfill. Landfill generated leachates have elevated concentrations of iron and zinc which are released as metal cans and other ferrous metals in landfills are oxidized (Gartner Lee 1991*). Iron concentrations in Leawood Creek sediments ranged from 2.1 to 3.5% (Table 8). The iron concentrations in limestone deposits throughout the world (average 1.7%, Bowen 1979) were significantly lower than those in Leawood Creek. Iron in the sediments of the intermittently dry creek adjacent to Leawood Creek (Figure 1) averaged 1.9% (Table 8). This was substantially lower than the iron concentrations in the nearby Leawood Creek sediments. Zinc co-occurs with iron in tin cans and was significantly elevated above background concentrations in the sediments of Leawood Creek (Tables 6 and 7). The high iron and zinc concentrations in Leawood Creek sediments coupled with the lower iron and zinc concen-

TABLE 7. Numbers of eight invertebrate taxa counted and (density) on 21 May 1991

Name of taxon	Site 1 # (density)	Site 2 # (density)	Site 3 # (density)	Site 4 # (density)	Total # (density)
Isopods	1 (11.1)	0 (0)	0 (0)	0 (0)	1 (3.0)
chironomids	27 (300.0)	29 (429.6)	16 (177.8)	4 (44.4)	76 (225.2)
Oligochaetes	0 (0)	0 (0)	1 (11.1)	0 (0)	1 (3.0)
Trichopterans	0 (0)	1 (14.8)	3 (33.3)	0 (0)	4 (11.9)
Culicoides	4 (44.4)	3 (44.4)	0 (0)	0 (0)	7 (20.7)
Nematodes	1 (11.1)	0 (0)	0 (0)	0 (0)	1 (3.0)
Snails					
Lymnaeidae	111 (1233)	32 (474.1)	6 (66.7)	0 (0)	149 (441.5)
Planorbidae	3 33.3	1 (14.8)	0 (0)	0 (0)	4 (11.9)
Total	147 (1633.)	66 (977.8)	26 (288.9)	4 (44.4)	243 (720)

TABLE 8. Neutron activation analysis of Leawood Creek sediment.

Elements	1A*	1B	1C	2A	2B	2C	3A	3B	3C	4A	4B	4C	Mean 1	Mean 2	Mean 3	Mean 4	Grand Mean**	St. Dev.**
Antimony	0.14	0.15	0.13	0.16	0.11	0.13	0.07	0.19	0.14	0.25	0.21	0.23	0.14	0.13	0.12	0.23	0.155	0.0507
Arsenic	2.90	3.20	3.50	4.30	2.20	2.20	1.90	3.90	3.20	5.0	5.2	5.1	3.2	3.1	3.0	4.03	3.33	1.114
Barium	120	180	120	110	100	120	97	130	130	190	170	110	140	110	119	156.67	143.17	31.283
Bromine	14	18	12	11	7.9	10	5.7	20.2	10	16	15	12	14.67	9.63	11.97	14.33	12.65	4.185
Cadmium	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	NA
Cerium	6.40	10.0	9.40	14.0	6.3	9.0	4.0	10.0	8.5	22.0	10	13	8.6	9.76	7.5	15.0	10.22	4.619
Cesium	0.56	0.89	0.69	0.74	0.56	0.57	0.41	0.06	0.67	0.94	0.67	0.66	0.71	0.63	0.65	0.76	0.69	0.153
Chromium	8.7	11.0	8.5	10.0	6.4	13	2.8	11	7.4	22	12	18	9.4	9.8	7.0	17.33	10.9	5.124
Cobalt	<2.0	2.1	2.4	2.2	<2.0	2.1	<2.0	2.2	2.5	2.5	2.2	<2.0	2.17	2.1	<2.23	2.23	2.18	0.190
Europium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.0276
Gold (ppb)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	0.2309
Hafnium	0.59	<0.5	1.30	1.20	<0.50	0.74	0.5	0.87	0.91	2.1	1.1	1.3	<0.8	<0.8	<0.8	1.5	0.965	0.471
Iridium (ppb)	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	<20.0	NA
Iron (%)	1.3	1.6	1.4	1.6	1.1	1.3	1.7	2.3	1.5	2.5	3.5	1.9	1.43	1.33	1.83	2.63	1.79	0.672
Lanthanum	3.0	5.30	5.30	6.50	3.30	4.8	2.4	3.3	4.3	10.0	5.3	7.4	4.53	4.87	3.33	7.57	5.07	2.097
Lutetium	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05	0.0199
Molybdenum	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	<0.50	0.1184
Nickel	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA
Rubidium	13.0	18.0	20.0	20.0	11.0	16.0	7.9	18.0	15.0	29.0	15.0	18.0	17.0	19.0	13.63	20.67	17.57	5.292
Samarium	0.72	1.20	1.20	1.40	0.61	1.0	0.42	1.0	0.93	2.4	1.1	1.8	1.04	1.00	0.78	1.76	1.11	0.536
Scandium	0.93	1.50	1.50	1.70	1.10	1.5	1.0	1.7	1.3	2.7	1.7	1.9	1.31	1.43	1.33	2.1	1.54	0.474
Selenium	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Silver	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	NA
Sodium (%)	0.10	0.16	0.13	0.17	0.20	0.2	0.11	0.15	0.15	0.43	0.21	0.27	0.13	0.16	0.13	0.3	0.18	0.183
Tantalum	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.0260
Tellurium	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	<10.0	NA
Terbium	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	0.0563
Thorium	1.0	1.1	1.50	1.50	0.83	1.1	0.58	1.3	1.2	2.4	1.2	1.5	1.2	1.14	1.02	1.7	1.27	0.452
Tin	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	<5.0	NA
Tungsten	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	NA
Uranium	1.6	1.7	1.6	1.4	1.6	1.5	1.4	1.7	1.5	1.3	1.7	1.3	1.63	1.5	1.53	1.43	1.52	0.148
Yttrium	<0.1	0.5	0.66	0.63	0.28	0.55	0.45	0.55	0.46	1.1	0.58	0.91	<0.45	0.49	0.49	0.86	0.57	0.245
Zinc	98	150	130	130	83	150	170	170	120	190	310	170	126	121	153.3	223.3	155.75	69.3
Zirconium	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	<100	5.774

*Site 1 was located at the base of the escarpment and site 4 at the top (Figure 1). Three replicates (A-C) were collected at each site. All values are mg per kg dry weight of sediment in this and subsequent tables with the following exceptions. Iron and sodium are reported as percentages (g per kg dry weight), iridium and gold are reported as ppb (micrograms per kg dry weight).

**Leawood Creek Grand Mean was calculated by adding the mean sediment concentrations for the four sample sites (Stations 1-4) and dividing by 4. NA (not applicable) was used to indicate that no analyses of the data was carried out because the number of values that were below the detection limit made it impossible to calculate a reliable grand mean and standard deviation.

TABLE 9. Dry creek sediment neutron activation analysis report*.

Element	Site 1	Site 2	Site 3	Control mean	Student "t" Values
Antimony	0.190	0.380	0.600	0.39	0.09
Arsenic	7.40	11.00	11.00	9.8	0.015*
Barium	120.0	310.0	340.0	256.7	0.065
Bromine	6.70	7.70	5.7	6.7	0.059
Cadmium	< 2.00	< 2.00	4.00	2.7	NA
Cerium	42.00	82.00	78.00	67.3	0.12
Cesium	1.90	4.80	8.40	5.0	0.089
Chromium	21.0	50.0	75.0	48.7	0.064
Cobalt	3.60	9.20	10.00	7.6	0.023*
Europium	0.56	0.94	0.69	0.73	0.34
Gold (ppb)	1.70	< 1.00	18.00	6.9	0.073
Hafnium	3.10	6.70	3.00	4.3	0.057
Iridium (ppb)	< 20.0	< 20.0	40	26.7	NA
Iron (%)	1.30	2.60	1.80	1.90	
Lanthanum	16.00	31.00	32.00	26.3	0.032*
Lutetium	0.34	0.66	0.51	0.6	0.032*
Molybdenum	< 0.50	< 0.50	4.30	1.8	0.30
Nickel	12.00	17.00	48.00	25.7	NA
Rubidium	35.00	88.00	140.00	87.7	0.10
Samarium	3.700	6.300	4.700	4.9	0.023*
Scandium	3.90	8.80	11.00	7.9	0.064
Selenium	< 1.00	1.3	2.00	1.3	NA
Silver	< 1.00	< 1.00	2.00	1.3	NA
Sodium (%)	0.180	0.450	2.200	0.94	0.27
Tantalum	0.380	1.100	0.850	0.78	0.067
Tellurium	< 10.00	< 10.00	20.00	13.3	NA
Terbium	0.48	0.86	0.59	0.80	0.029*
Thorium	4.30	9.10	9.10	7.5	0.043*
Tin	< 50.00	< 50.00	< 50.0	66.67	NA
Tungsten	< 0.500	< 0.500	2.700	1.23	NA
Uranium	1.100	2.200	2.200	1.8	0.038*
Yttrium	1.50	2.80	2.30	2.2	0.028*
Zinc	< 50.0	100.0	100.0	83.3	0.038*
Zirconium	<100.0	170.0	<100.0	156.67	0.034*

*Leawood Creek mean sediment composition for the 34 elements listed above was compared with the mean for the same elements from samples taken from the intermittently dry creek by using Tukey's "t" test. One asterisk indicates values for which $P < 0.05$. NA (not applicable) means that no analyses of the data were done due to the number of values that were below the detection limit.

trations in the nearby intermittently dry creek points to landfill leachate contamination as a likely explanation.

Sulphur in Leawood Creek (2830 to 3530 ppm, Gartner Lee 1991*) exceeded the guidelines for the upper limits of normal sulphur concentrations (Ontario Ministry of the Environment 1979*). The high concentrations of sulphur in Leawood Creek sediments was likely due to groundwater influences as the local groundwater displays a high level of sulphur (Gartner Lee 1991*) and spring water enters Leawood Creek at a number of sites near its headwaters.

Biological Monitoring of Macroinvertebrates in Leawood Creek

Most of the chironomid species collected in the 1991 winter sampling period belonged to the

Orthocladiinae family (Table 10) and most of these belonged to species which are tolerant of a wide range of organic and inorganic pollutants (Wiederholm 1983). In addition, *Cricotopus sylvestris* (Table 10) is also relatively tolerant of a wide variety of man-made pollutants (Wiederholm 1983).

Chironomid generic richness (only five species were collected in winter) was low as was chironomid density (37 m⁻²) (Tables 1 and 2). Normally, more taxa are encountered in winter in uncontaminated streams in Canada (Oliver and Roussel 1983). Chironomid diversity (H) was also extremely low (less than 1.5, Table 7). Chironomid density was also quite low in spring (Table 5). Chironomid density increased with distance downstream from the landfill. Station 4 located nearest the landfill had a

TABLE 10. Chironomid density (number of individuals m^{-2}) in winter

<i>Diplocadius cultiger</i>	<i>Cricotopus sylvestris</i>	<i>Tvetenia bavaricum</i>	<i>Eurothocladius</i>	<i>Paraphenocladius</i>	Total Density
32	6	18	8	336	400

mean chironomid density of 44 individuals m^{-2} while Station 1, located farthest from the landfill, displayed a mean chironomid density of 300 m^{-2} (Table 7). In spring, chironomid densities increased but were still low in comparison to those described by Oliver and Roussel (1983).

The most abundant chironomid genus in Leawood Creek in winter was *Tvetenia bavarica* (41.2%). *Tvetenia* larvae resemble *Eukiefferiella* and are distinguished by their longer body setae and well developed procercus (protuberances located next to the anal setae). *Tvetenia bavarica* larvae inhabit flowing waters and are widely distributed. Seven species have been recorded to date (Wiederholm 1983).

Eurothocladius sp. (26.1% of the total winter chironomid population) was the next most abundant genus. *Euorthocladius* is a subgenus of *Orthocladius*. *Euorthocladius* inhabits flowing waters and is widespread throughout the world with the exception of the antarctic. There are over 100 described species (Wiederholm 1983).

Paraphaenocladius (4% of the total winter chironomid population was comprised of this genus). Most species of this genus are terrestrial inhabiting damp soil by springs and seeps. About 14 *Paraphaenocladius* species are known from the holarctic region (Wiederholm 1983).

The total winter invertebrate density (486 m^{-2} , 453 m^{-2} for the six most common taxa and 33 m^{-2} for all other taxa combined) was extremely low even for winter. Chironomids, Coleoptera (beetle larvae) and snails (primarily Planorbidae) were the dominant taxa (Table 11).

In mid May, total invertebrate numbers nearly doubled to 720 m^{-2} (Table 7) which is well below the average of over 1000 individuals m^{-2} described by Cooper (1965) for a stream in Michigan. At sites 3 and 4, the complete absence (January to June 1991) of all crustaceans (considered by many to be more pollution sensitive than most other kinds of aquatic invertebrates) also supports the view that contamination of the water by reduced elements such as iron, as noted earlier, had probably led to their absence at sites nearest the landfill. Crustacean densities in an escarpment stream (Bird and Hale 1992) and in a

Michigan stream ranged from 184 to 4870 m^{-2} (Cooper 1965).

Biological Monitoring of Periphyton in Leawood Creek

Round (1961) estimated the number of epipellic diatoms in winter in Lake Windemere, England, and concluded that in November and December the density was at its annual minimum of 200 cells cm^{-2} . Similar values were observed in Leawood Creek in winter. In spring, epipellic diatom densities in Leawood Creek peaked at 3000 diatoms cm^{-2} . A number of the diatom taxa observed in Leawood Creek were pollution tolerant species Patrick and Reimer (1966 and 1975), Prescott (1980), Beaver (1981*), Camburn and Kingston (1985*).

Cyanophyte densities (Blue-green algae) in Lake Windemere, England were about an order of magnitude lower than those of the diatoms (Round 1961). A similar ratio was observed in Leawood Creek (Tables 1 and 2).

During the Leawood Creek study, the dominant primary producer in the Creek was a branching filamentous green alga, *Cladophora*. This multinucleate alga was often found in association with a large number of aquatic snails (*Physa* and *Lymnaeidae*). In a few places the *Cladophora* formed a veritable green "carpet" on the bottom of the Creek. Elsewhere it formed dense clumps of intertwined filaments. In the upper stretches of the creek, these clumps were coated with iron oxides and when the *Cladophora* died, left behind an iron oxide encrusted matrix of empty tubes. *Cladophora* ranged in abundance from a low of 2100 cells cm^{-2} at Station 4 to a high of 12 000 cells cm^{-2} at Station 3 (Tables 1 and 2). Thus we speculated that nutrients released by the landfill or the ground water may have also stimulated filamentous algal growth in the Creek. This, in turn, could explain the high herbivore snail densities observed (941 individuals at Station 3, Tables 1 and 2) as these snails were observed to graze on *Cladophora*.

Chemolithotrophic Bacteria in Leawood Creek

For the period, 1989-1991, the rocks in Leawood Creek became increasingly stained by red deposits of

TABLE 11. Invertebrate density (number of individuals m^{-2}) in winter

Chironomids	Isopods	Coleopterans	Oligochaetes	Lymnaeidae	Planorbidae
400	3	12	7	3	28

iron oxides and iron encrusted bacteria. In April, a thin iron oxide film began to accumulate on the study rocks at Site 4. This red film thickened in May and declined in June when chlorinated tap water from the City of St. Catharines entered the Creek. Samples of the red film coating the rocks were removed in May 1991 and sent to H. L. Ehrlich who identified the dominant organisms in the film as *Gallionella*. The lower portion of the creek differed substantially from the upper (escarpment) section because it lacked the striking red bacterial film.

Gallionella is referred to as a "gradient" organism; i.e., it grows best under a strong gradient of low oxygen tensions ranging from (0.1-1 mg of O_2 per liter) and in a redox E_h range of +200 to +320 mV (Hanert 1981). It is also a mesophile preferring temperatures between 10 and 30°C, although growth in nature of some strains has been observed up to 47°C. It prefers a pH range of 6.0-7.6 but has been found at higher pH's (Hanert 1981). Its low oxygen requirement explains why this organism can catalyze Fe^{2+} oxidation at neutral pH. The iron under these partially reduced conditions autoxidizes only slowly (Wolfe 1964).

The Red Stain Problem

Wilf Ruland, a hydrogeologist and private consultant, provided data to support the view that as the area of the Glenridge Landfill increased to handle more and more solid waste, more surface water was being intercepted reducing the amount entering the water table near the Landfill (Ruland 1992*). He predicted that iron-rich saline ground water would rise toward the surface (Ruland 1992*). By 1989 the ferrous iron concentrations in Leawood Creek near Stations 3 and 4 was so high that sulfur oxidizing bacteria such as *Gallionella* began colonizing the substrate at these sites causing an unsightly red slime encrustation to appear.

Recognizing that there was a problem, the City of St. Catharines began diverting all the water from Leawood Creek to the sewage treatment plant and replacing the flow with dechlorinated City tap water. This diversion of leachate contaminated surface water to the sewage treatment plant permitted the ground water to come even closer to the surface of the escarpment face. One repercussion of this was the numerous reports of wilting and chlorosis of escarpment tree species growing below the Glenridge Landfill. As a result of these reports, the Phytotoxicology section of the Ontario Ministry of the Environment carried out a study of the impact of increased salinity in shallow ground water on the escarpment tree species near the Glenridge Landfill (Ontario Ministry of Environment 1993*). The observed changes of some hillside trees associated with the City's alteration of the normal groundwater flow pattern was attributed to the deep groundwater with high salinity moving closer to the escarpment

surface as predicted by Ruland (1990*). To prevent the loss of more escarpment trees, the City of St. Catharines delivered tap water to the top of the escarpment to replace the surface water that they had diverted to the sewage treatment plant. Concern was expressed by the Glenridge Landfill Citizens Committee that this set a dangerous precedent in which anyone polluting an escarpment stream rather than being required to decontaminate the leachate contaminated surface waters could simply divert its flow and pipe city water in to replace the diverted flow. In 1992, the Niagara Escarpment Commission (created in the Niagara Escarpment Protection Act of 1972*) decided not to allow any more landfills on the escarpment in order to prevent problems like those experienced at the Glenridge Landfill site from occurring elsewhere in the future.

As a result of the above problems, and of problems associated with leachate overflows entering Leawood Creek, a few home owners near the Creek who were concerned about reports of leachate entering the Creek employed consulting companies to carry out fecal coliform tests and water chemistry of the Creek. In addition, the original designers of the Landfill, Gartner Lee Associates carried out numerous studies of the ground water and surface waters near the Landfill. A Biological Baseline Survey of Leawood Creek was carried out by Bird and Hale Environmental Consulting Ltd. (1992*) and various MOE studies of water quality were conducted following leachate releases into the Creek. These studies indicated that Leawood Creek, once a beautiful natural escarpment stream, has been contaminated by fecal and slime bacteria, organic chemicals and elevated levels of heavy metals and electrolytes. As a result, the stream is colonized by sludge worms, blood worms (chironomids) and a few other pollution tolerant invertebrate taxa.

The impact of a municipal landfill on a natural escarpment creek has resulted in the virtual elimination of the pollution sensitive stream invertebrates such as scuds, mayflies and caddisflies. These organisms have been replaced by pollution tolerant sludge worms, nematodes, snails, beetle larvae and blood worms. Based on comparisons with an unimpacted nearby intermittent stream, some of the sediment chemistry of impacted Leawood Creek has changed over the last fifteen years following land filling operations. Pollution tolerant taxa and slime bacteria became the dominant species inhabiting the upper reaches of Leawood Creek until the City of St. Catharines began diverting dechlorinated City tap water into the Creek. Although we stopped sampling the Creek once the water from the Glenridge Landfill was diverted to the City of St. Catharines we returned to observe the Creek's condition and were struck by the disappearance of the red encrusting iron bacteria.

As the urban landfill expanded its size, more and more rain water was intercepted by the landfilled area and the City diverted this intercepted rain water to its sewage treatment facility. As a result, less rain water was able to percolate downward into the water table. By reducing infiltration the volume of the ground water entering Leawood Creek decreased but the salinity of the ground water which did enter the Creek increased. This resulted in an increase in the salinity of the water in Leawood Creek (Gartner and Lee Ltd. 1990*, 1991*; Ruland 1992*). In addition, occasional leachate discharges to the creek reportedly occurred prior to our 1991 study. The result of all of this has been the reduction in sediment and surface water quality and the reduction in biotic species diversity.

Iron, various rare earths and zinc were significantly elevated above background levels in the sediments of Leawood Creek. The elevated zinc concentrations may have prevented amphipods (crustaceans) from becoming abundant in the upper reaches of the Creek. Before the landfill was created in 1976 amphipod grazers were common in both the upper and lower sections of the Creek. In 1991, amphipods were observed only in the lower part of the study area (i.e., south of Lockhart Drive, Figure 1). In the absence of these herbivores, the herbivorous snails in the Creek may have thrived as there was little competition for food.

Sediment iron concentrations in Leawood Creek ranged from 2.1% to 3% with a mean of 1.8%. This was higher than iron concentrations in the nearby dry creek and significantly higher than in limestone deposits throughout the world (1.7%, Bowen 1979).

Surface water pollution is a continuing and increasing problem throughout the world. Its effects can be catastrophic, altering the environment dramatically and permanently (Ellis et al. 1990).

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Stream Fishes of the Red River of the North Basin, United States: A Comprehensive Review

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During 1993 and 1994 we obtained all known records of fish surveys conducted in the Red River of the North (Red River) basin in the United States. From these surveys, which occurred from 1892–1994 at 1026 stream sites by several state and federal agencies, colleges, and universities and from additional sampling conducted 1995–1997, it was determined that the ichthyofauna of the basin includes 84 species representing 19 families. Twenty-nine species were cyprinids, and 10, 9, 9, and 6 species were percids, centrarchids, catostomids, and ictalurids, respectively. The White Sucker (*Catostomus commersoni*), Fathead Minnow (*Pimephales promelas*), and Common Shiner (*Luxilus cornutus*) were the most common species, occurring at 60%, 53%, and 47% of sites sampled, respectively. Species which were most rare included the Largescale Stoneroller (*Camptostoma oligolepis*), Pugnose Shiner (*Notropis anogenus*), and Mottled Sculpin (*Cottus bairdi*), all found at <1% of sites. For 15 species, distributions were restricted either mostly or entirely to the eastern half of the Red River basin; eight of these species were found almost exclusively in the Otter Tail River drainage. The Longnose Gar (*Lepistosteus osseus*) was reported from the lower Otter Tail River in 1892, but likely no longer exists in the basin and is not considered a part of the current ichthyofauna. The Lake Sturgeon (*Acipenser fulvescens*) has not been collected from waters of the basin since the mid-1950s, but the species was reintroduced in the Otter Tail and Pelican rivers in 1997. Moderate reductions in range were also noted for several other species over the past century, including the Brassy Minnow (*Hybognathus hankinsoni*), Pearl Dace (*Margariscus margarita*), Hornyhead Chub (*Nocomis biguttatus*), Blacknose Shiner (*N. heterolepis*), Brown Bullhead (*Ameiurus nebulosus*), Banded Killifish (*Fundulus diaphanus*), Iowa Darter (*Etheostoma exile*), and River Darter (*Percina shumardi*).

Key Words: midwestern stream fishes, species richness, distribution patterns, temporal variability, extirpation, Red River, North Dakota, Minnesota.

The fishes of the Red River of the North (Red River) basin have been studied for more than a century, with the first published records of species distribution provided by Woolman (1896). The Red River basin in the United States includes portions of Minnesota, North Dakota, and a small portion of South Dakota. Historically, most surveys of fishes have focused on only North Dakota streams or only Minnesota streams, and there has never been a comprehensive site-specific study of Red River basin fishes. A study is required because two published lists of fish species present in the Red River basin are not in agreement; Crossman and McAllister (1986) listed 75 fish species for the Red River basin in the United States, while Underhill (1989) listed 80 species. Further, since the drainage basin crosses state boundaries, relatively little has been published about the distribution of stream fishes on a basin-wide scale.

Because of an apparent lack of any comprehensive distributional studies, the specific objectives of this study were to determine (1) the total number of fish species existing both historically and currently in streams of the Red River basin; (2) those fish species which currently have highly restricted distributional patterns; and (3) any significant temporal changes in

the distribution of each stream fish species. We reviewed all known published and non-published records of fish distribution in the Red River basin to produce a computerized database, and then plotted species distributions using a geographic information system (GIS). We also attempted to reconcile discrepancies among published lists of fish species in the Red River basin.

Study Area

The Red River is a northward-flowing river formed by the confluence of the Otter Tail and Bois de Sioux rivers at the neighboring cities of Wahpeton, North Dakota, and Breckenridge, Minnesota. The Red River forms the boundary between North Dakota and Minnesota as it meanders for 640 km to the international border at Manitoba, Canada (Figure 1). The straight-line distance from the origin of the Red River to Manitoba is 300 km. In Manitoba, the Red River joins with the Assiniboine River at Winnipeg and then drains into the south end of Lake Winnipeg. Waters from Lake Winnipeg flow via the Nelson River into Hudson Bay; thus, the Red River is a portion of the Hudson Bay drainage system.

Tributaries: The Red River is joined by several major tributaries as it flows toward Canada. Streams flowing from the west include the Wild Rice, Sheyenne, Elm, Goose, Turtle, Forest, Park, and Pembina rivers in North Dakota (Figure 1). Streams flowing from the east include the Buffalo, Wild Rice, Sandhill, Red Lake, Snake, Tamarac, Two, and Roseau rivers in Minnesota. The Pembina River arises in Canada and its mouth is at the Red River in the United States. The Roseau River arises in the United States and its mouth at the Red River is in Canada. Two major tributaries are named Wild Rice, a potential source of confusion.

Drainage basin: The Red River drainage basin in the United States encompasses a total of 101 526 km², which includes 53 924 km² in North Dakota, 46 118 km² in Minnesota, and 1484 km² in South Dakota (U.S. Army Corps of Engineers 1980) (Figure 1). Glacial Lake Agassiz deposited between 46 and 91 m of materials over the basin, shaping a broad, flat lake plain at its center surrounded by rolling uplands, wetlands, and lakes along the western and eastern margins. The fertile, productive soils and flat landscape have resulted in 66% of the total basin land area being used as cropland, and 8% as pasture and rangeland (Stoner et al. 1993). Forests, open water, and wetlands comprise the remaining 26% of the land area. Beach ridges and deltas of glacial Lake Agassiz (Teller and Bluemle 1983) lie at the transition zone between the flat lake plain and the upland areas that were not water covered. The most extreme transition occurs in the northwestern basin, where the Pembina Escarpment rises 183 m from the lake plain and forms an area of rolling hills (U.S. Army Corps of Engineers 1980). Stream slopes range from 0.4–1.0 m/km in upland areas to about 0.2–0.3 m/km in the lake plain (Stoner et al. 1993).

The Red River basin is bordered by the James River basin (Missouri River drainage) and the Devils Lake closed basin to the west, the Minnesota River basin (Mississippi River drainage) to the south, and the Mississippi and Rainy river (Hudson Bay drainage) basins to the east. Several of the headwaters of the Otter Tail, Wild Rice, and Red Lake rivers in the eastern portions of the Red River basin are in close geographic proximity to those of the Mississippi River, whereas streams in the western portions of the Red River basin are more distant from streams of neighboring drainage basins.

Methods

Collection of Fish Survey Data

Published and unpublished fish survey records for all streams in the Red River basin were collected and analyzed during 1993 and 1994. Also, we contacted fisheries biologists in the region during 1997 to determine if any recent changes had been noticed in fish distribution and to update our species list.

Search techniques during 1993 and 1994 included (1) a review of periodicals, theses, and government documents at the North Dakota State University library and other regional institutions through interlibrary loan; (2) personal visits and searches of files at the Minnesota Department of Natural Resources, Section of Fisheries, Region 6 Headquarters in Bemidji, Minnesota, under the guidance of Lee Sundmark and Robert Strand; (3) personal visits to the Bell Museum of Natural History, University of Minnesota and discussions with James Underhill and Jay Hatch; (4) written communications with Pat Bailey, Minnesota Pollution Control Agency; Kevin Cummings, Illinois Natural History Survey; Susan Jewett, Smithsonian Institution; Douglas Nelson, University of Michigan, Museum of Zoology; Eric Pearson, North Dakota State Department of Health; and Randy Kreil, North Dakota Game and Fish Department; and (5) communications by telephone with Luther Aadland, Minnesota Department of Natural Resources, Ecological Services Section; Gene Van Eeckhout, North Dakota Game and Fish Department; and Paul Glander, Minnesota Department of Natural Resources, Section of Fisheries. Unpublished surveys by members of the Department of Zoology, North Dakota State University were compiled and also incorporated. Methods of fish collection have included gears of various types, such as seines, trap nets, gill nets, and electroshocking devices (portable-generator type in small streams and large boat-type in downstream reaches and the Red River main stem).

Data storage: For sites sampled in 26 major tributaries and the Red River main stem, the stream, primary investigator, ecoregion classification, coordinates in latitude and longitude, date, and fish species occurrences in binary (presence or absence) format were tabulated in Quattro Pro (Borland, version 5.0). Records from the Pembina and Roseau rivers are only from the portion of each drainage that lies within the United States, downstream from the border for the Pembina River and upstream from the border for the Roseau River. Location information (usually township, range, and section) was used to plot all sampling sites on USGS 1:250 000 scale quadrangle maps. Latitude and longitude coordinates (decimal degrees) for each site were obtained using a Summagraphics Microgrid II digitizing pad with a Gateway 486DX personal computer running TOSCA (1993) software.

Production of species list: Based on stream survey records and lake surveys (conducted by Minnesota Department of Natural Resources), a comprehensive species list for the Red River basin was produced. Most fishes listed were found at multiple sites by several investigators in recent years. Not included on the list were incidental records of nonnative fishes (such as Goldfish, *Carassius auratus*, and Golden

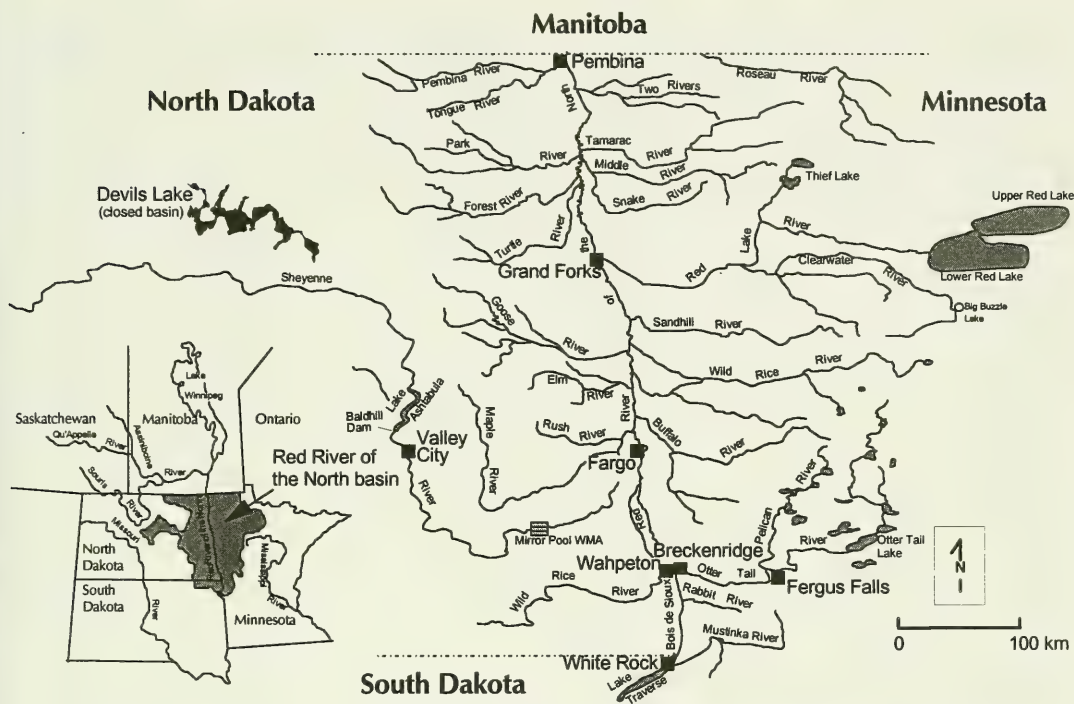


FIGURE 1. Streams in the Red River of the North basin in the United States for which fish survey records were obtained.

Orfe, *Leuciscus idus*) introduced from local aquaria and likely not part of naturally reproducing populations, and hybrid fishes, most of which were centrarchids. Also not included were species which were determined to be recorded in error in the literature. In cases where species were reported that had not been found historically in the Red River basin and appeared erroneous, the primary investigators of the reports were contacted to determine if voucher specimens of the species had been collected. Most errors were due to misidentification of fishes in the field. Common and scientific names of fish species followed those of the American Fisheries Society (Robins et al. 1991).

Mapping of Fish Distribution

Stream digitizing: All nonintermittent streams and lakes in the Red River basin were digitized from USGS 1:250 000 scale quadrangle maps using a Summagraphics Microgrid II digitizer and TOSCA (1993) software. Streams were entered as lines and lakes as polygons with separate files created for each quadrangle map. The VCONCATE module of TOSCA was then used to combine all stream files and all lake files into two complete coverages (layers). These layers then served as the base map upon which species distribution points were plotted.

Species distribution: For each fish species, a file containing the year and coordinates in latitude and

longitude of all sites where the species occurred was created from the Quattro Pro database. The coordinates were then sorted by year into three time periods (early, middle, and late), saved as separate files, and downloaded into an IDRISI (1993) geographic information system (GIS). In IDRISI the files were saved as vectors in binary data format using the CONVERTV module. Hard copies of distribution maps were created by overlaying vector files and printing from TOSCA (1993).

Results

History of Stream Fish Survey Effort in the Red River Basin

From records of stream fish surveys, data were acquired from 1026 sampling sites located throughout the Red River basin during the time period from 1892-1994 (Table 1). Although records of the University of Michigan, Museum of Zoology, and the Smithsonian Institution indicated that samples of fishes were collected during 1857 from the Red and Maple rivers by R. Kennicott and during 1860 from the Middle and Sandhill rivers by S. H. Scudder (Koel 1997), published survey records did not appear until the 1890s. The records from the mid-1800s do not contain accurate site location descriptions; none of these records were plotted on species distribution maps.

TABLE 1. Sources of fish survey data used to produce species distribution maps. Streams included the Red (1), Pembina (2), Tongue (3), Park (4), Forest (5), Turtle (6), Goose (7), Elm (8), Rush (9), Maple (10), Sheyenne (11), Wild Rice, ND (12), Bois de Sioux (13), Mustinka (14), Rabbit (15), Otter Tail (16), Pelican (17), Buffalo (18), Wild Rice, MN (19), Sandhill (20), Red Lake (21), Clearwater (22), Snake (23), Middle (24), Tamarac (25), Two (26), and Roseau (27) rivers for various years and number of sites.

Source	Stream	Year(s)	Sites
1 Bell Museum of Natural History, University of Minnesota	13,14,15,16,17,18,19,20,21,22,23,24,25,26,27,28	1955-1979	292
2 Copes and Tubb (1965)	2,3,4,5,6,7,8,9,10,12	1964	62
3 Enblom (1982)	27	1976	14
4 Feldman (1963)	5	1962	8
5 Hankinson (1928)	1,2,4,11	1922	8
6 Hanson et al. (1984)	16	1980	14
7 Illinois Natural History Survey	6	1978	1
8 Kreil and Ryckman (1987)	2	1987	15
9 MN Department of Natural Resources, Ecological Services Section ¹	1,2,3,4,5,6,7,10,11,13,14,15,16,17,18,19,20,21,22,23,24,25,26,27	1983-1994	164
10 MN Department of Natural Resources, Section of Fisheries	16,21,22,24,25,27	1975-1992	53
11 Naplin et al. (1977)	19	1976	10
12 ND Game and Fish Department	1,8,9,11,12,13	1976-1989	76
13 ND Department of Health ¹	1,2,3,4,5,6,7,8,9,10,12,13	1993-1994	33
14 North Dakota State University, Department of Zoology	9,11,12,18,20,22	1993-1994	33
15 Olson (1932)	18,19,20,21,22,23	1932	18
16 Peterka (1978)	11	1977	12
17 Peterka (1992)	2,3,4,5,6,7	1991	48
18 Renard et al. (1983)	21	1976-1977	26
19 Renard et al. (1985)	1	1984	41
20 Russel (1975)	11,12	1974	38
21 Tubb et al. (1965)	11	1964	25
22 Wilson (1950)	11	1950	9
23 Woolman (1896)	1,2,3,4,5,6,7,10,11,14,16,18,21	1892	18
24 University of Michigan, Museum of Zoology ²	6,10,11,16,21	1892-1951	9

¹Several sites were sampled during a cooperative effort by the Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, North Dakota Department of Health, U.S. Environmental Protection Agency, and U.S. Geological Survey.

²Data also included collections by Hankinson (1922) and Woolman (1892).

The first published document regarding a survey of fishes in the Red River basin was provided by Woolman (1896), who sampled 18 sites on 13 streams. Other published records from surveys during 1892-1961 (early period) included Brannon (1912), Hankinson (1928), Olson (1932), Wilson (1950), Bailey and Allum (1962), Phillips and Underhill (1971), and Eddy et al. (1972). Unpublished records for this period existed at the University of Michigan, Museum of Zoology and the Bell Museum of Natural History, University of Minnesota. One-hundred twelve sites were sampled between 1892 and 1961 (Figure 2), and most streams were sampled for fishes at least at one site; however, only 51 sites were sampled in the basin prior to 1950. The Elm, Rush and Rabbit rivers, and the Wild Rice River in North Dakota were not sampled.

The 1960s marked the beginning of 30 years of

relatively intensive sampling of stream fishes in the Red River basin. Surveys were conducted by several state agencies and universities on all major streams and several minor tributaries. Published records from surveys during 1962-1977 (middle period) were provided by Feldman (1963), Copes (1965), Tubb et al. (1965), Copes and Tubb (1966), Reedstrom (1967), Reedstrom and Carlson (1969), Eddy and Underhill (1974), Russel (1975), Duerre (1975), Naplin et al. (1977), Peterka (1978), Owen et al. (1981), Enblom (1982), and Renard et al. (1983). Unpublished records for this period existed at the Bell Museum of Natural History, University of Minnesota. During 1962-1977, 439 sites were sampled for fishes (Figure 2). Most streams were sampled at multiple sites including both headwater and downstream reaches during this relatively short (16 year) time span. The streams for which records were lacking during the

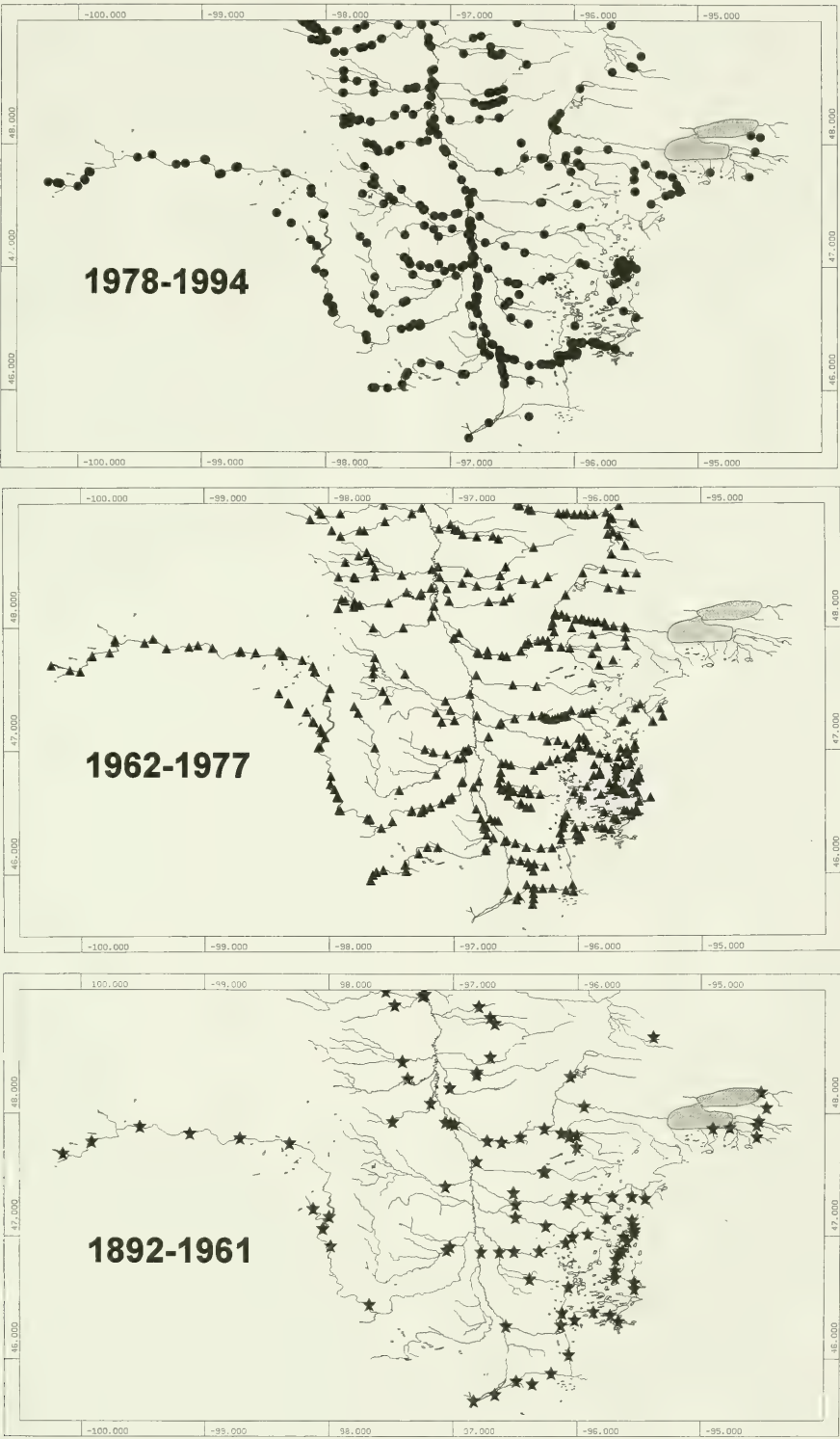


FIGURE 2. Stream sites sampled for fishes in the Red River of the North basin during 1892–1961 (early period, $n = 112$), 1962–1977 (middle period, $n = 439$), and 1978–1994 (late period, $n = 475$).

middle period included those draining into the Upper and Lower Red Lakes in the eastern basin and the Red River from its origin at Breckenridge, Minnesota, to the Canadian border.

In recent years, relatively intensive sampling of many streams in the Red River basin has continued. Published records from surveys during 1978-1994 (late period) were provided by Phillips et al. (1982), Hanson et al. (1984), Renard et al. (1985), Kreil and Ryckman (1987), Duerre (1988), Peterka (1992), Schmitt (1993), and Feigum (1995). Unpublished records for this period were obtained from the Minnesota Department of Natural Resources, Minnesota Pollution Control Agency, North Dakota Department of Health, U.S. Environmental Protection Agency, and the U.S. Geological Survey. These agencies have been a part of either the USGS National Water Quality Assessment program (Stoner et al. 1993) and/or the development of an index of biotic integrity for fishes in the basin (Goldstein et al. 1994). During 1978-1994, 475 sites were sampled (Figure 2). As during the middle period, most streams were sampled at multiple sites during this 17-year time span, however, the Mustinka River was sampled at only one site. Notably, from work by Renard et al. (1985) and others (Table 1), the Red River main stem was intensively sampled for fishes.

The Fishes of the Red River Basin

Eighty-four fish species representing 19 families have been reported by investigators and currently constitute the ichthyofauna of the Red River basin (Table 2). Of these, 77 are considered native to the basin and seven are introductions, including the Rainbow Trout (*Oncorhynchus mykiss*), Brown Trout (*Salmo trutta*), Brook Trout (*Salvelinus fontinalis*), Common Carp (*Cyprinus carpio*), Flathead Chub (*Platygobio gracilis*), Muskellunge (*Esox masquinongy*), and White Bass (*Morone chrysops*). All but the cyprinids were introduced for sport-fishery purposes in the basin, and while most populations of salmonids and Muskellunge have been maintained by state and/or federal stocking programs, the White Bass has apparently reproduced successfully in the basin following its introduction into Lake Ashtabula (Sheyenne River) in 1953; it was first documented in Lake Winnipeg in 1963 (Scott and Crossman 1973). The Muskellunge has recently become common in samples taken from the lower Otter Tail River (Luther Aadland, Minnesota Department of Natural Resources, personal communication 1997), although the species is stocked in lakes of the upper reaches of the drainage. The Common Carp has occurred at 25% of stream sites in the Red River basin since its introduction in the early 1900s. However, the Baldhill Dam upstream from Valley City has apparently been an effective barrier to the movement of this species into the upper Sheyenne River, as it has not been collected

there. The Flathead Chub (a single specimen) has been collected at only one site, on the Red River downstream from Fargo, North Dakota, in 1984. The Flathead Chub is abundant in the Missouri River drainage in western North Dakota, but also is native to the Hudson Bay drainage in Canada (Scott and Crossman 1973).

The Lake Sturgeon (*Acipenser fulvescens*) has not been collected in the basin in recent years, although there have been efforts to re-establish a viable population. During the fall of 1997, 50 Lake Sturgeon were reintroduced into Detroit Lake (Pelican River) and 200 into the lower Otter Tail River (Paul Glander, Minnesota Department of Natural Resources, personal communication 1997). The origin of these fishes was the Rainy River. Historical accounts of Lake Sturgeon include that by Strand (Minnesota Department of Natural Resources, personal communication 1994), who reported a single specimen caught during the 1950s in a walleye net in the Red Lakes. A 46 kg sturgeon was taken from Lake Lida (Pelican River) in 1920; an 80 kg sturgeon, taken from White Earth Lake (Wild Rice River) in 1926, is on display at Cedar Crest Resort, White Earth, Minnesota.

The Longnose Gar (*Lepistosteus osseus*) was reported by Woolman (1896) from the Otter Tail River near Breckenridge. Only one specimen was collected, but local people reported it as abundant in the deep parts of the stream at that time. The specimen is on record at the Bell Museum of Natural History, University of Minnesota, but we do not include this species as being part of the current ichthyofauna of the Red River. Longnose Gar are common in the lakes of the Pomme de Terre River drainage; this drainage is in close geographic proximity to the lower Otter Tail River.

Overall, White Sucker (*Catostomus commersoni*) was the most common species at stream sites sampled in the Red River basin, having been found at 60% of sites sampled from 1962-1994. Also relatively common were Fathead Minnow (*Pimephales promelas*), Common Shiner (*Notropis cornutus*), Northern Pike (*Esox lucius*), and Johnny Darter (*Etheostoma nigrum*), found at 53%, 47%, 39%, and 39% of sites, respectively. The most rarely occurring species in the basin included Largescale Stoneroller (*Camptostoma oligolepis*), Pugnose Shiner (*Notropis anogenus*), Flathead Chub (*Platygobio gracilis*), and Mottled Sculpin (*Cottus bairdi*), all found at <1.0% of sites.

The highest percentage of fishes from the Red River basin were from the family Cyprinidae, which was represented by 29 fish species (34%), while 10 species (12%) were Percidae, 9 species (11%) Centrarchidae, 9 species (11%) Catostomidae, 6 species (7%) Ictaluridae, and 5 species (6%) Salmonidae. The families Petromyzontidae, Hiodontidae, and Esocidae were each represented by

two species (2%), and 10 families were represented by only one species (Table 2).

Discussion

From records of stream and lake surveys we documented 77 native and seven introduced fish species as currently present in the Red River basin. Crossman and McAllister (1986) listed 75 species for the Red River basin, and Underhill (1989) listed 80 species. Crossman and McAllister (1986) did not include Bowfin (*Amia calva*), Rainbow Trout, Brown Trout, Northern Hogsucker (*Hypentelium nigricans*), Smallmouth Buffalo (*Ictiobus bubalus*), Largemouth Stoneroller (*Camptostoma oligolepis*), Common Carp, Yellow Bullhead (*Ameiurus natalis*), Central Mudminnow (*Umbra limi*), Largemouth Bass (*Micropterus salmoides*), or Rainbow Darter (*Etheostoma caeruleum*). The Logperch (*Percina caprodes*) and Bigmouth Buffalo (*Ictiobus cyprinellus*) were listed, but only for the Canadian reaches of the Red River. The Brook Trout, Pugnose Shiner, Green Sunfish (*Lepomis cyanellus*), and Mottled Sculpin (*Cottus bairdi*) were listed for other drainage basins in Canada, but not the Red River basin.

Crossman and McAllister (1986) listed the Northern Brook Lamprey (*Ichthyomyzon fossor*), Bullhead Minnow (*Pimephales vigilax*), and Longear Sunfish (*Lepomis megalotis*) for the Red River in the United States. No records of these species were found during the present study, and verification of records listed by Crossman and McAllister (1986) could not be obtained (E. J. Crossman, Royal Ontario Museum, personal communication 1994). The Northern Brook Lamprey is present in the Hudson Bay drainage in Manitoba, the Great Lakes drainage of Ontario and Quebec, and in drainages in Wisconsin, Michigan, Ohio, and Missouri in the United States (Lanteigne 1992). The northernmost distribution of the Bullhead Minnow is the Mississippi River drainage in southern Minnesota and Wisconsin (Lee et al. 1980; Becker 1983). Its range extends south through Texas and the Gulf of Mexico. The Longear Sunfish has been reported from the Hudson Bay drainage in Canada (Scott and Crossman 1973) and the upper Mississippi and Rainy river drainages (Underhill 1989), but the species is primarily distributed through the east-central and south-central United States (Lee et al. 1980; Becker 1983). Also included by Crossman and McAllister (1986) for the Red River in the United States were two species with a question mark. The Silvery Minnow (*Hybognathus nuchalis*) and Longnose Sucker (*Catostomus catostomus*) were listed, but results of the present study indicate that they do not occur in the system.

Underhill (1989) listed 80 fish species for the Red River, including 75 native and five introduced. Records of all these species were found during the present study. However, Underhill (1989) did not

include Smallmouth Buffalo, Yellow Bullhead, Muskellunge, Orangespotted Sunfish (*Lepomis humilis*), or Mottled Sculpin. The Smallmouth Buffalo has only recently been collected from the Red River basin; several individuals were collected from the lower Otter Tail River in 1996 and vouchers have been deposited at the Bell Museum of Natural History (Luther Aadland, Minnesota Department of Natural Resources, personal communication 1997). It is possible that this species is a recent immigrant from the upper Minnesota River basin to the south, as a natural connection exists between the Red and Minnesota river basins during years of high water (Clambey et al. 1983). The Yellow Bullhead is a native species which has occurred primarily in the lakes of the Otter Tail and Pelican river drainages. Its distribution is restricted entirely to the eastern reaches of the Red River basin (Figure 3). The Muskellunge is an introduced species found primarily in lakes of the Otter Tail and Pelican river drainages, although it has also been stocked in the Sheyenne River (Gene Van Eeckhout, North Dakota Game and Fish Department, personal communication 1994). The Orangespotted Sunfish has occurred primarily in the Sheyenne River, although it has been taken near the mouth of the Otter Tail River and at Lake Traverse (Figure 3). The Mottled Sculpin was reported by Minnesota Department of Natural Resources in unpublished records from sites on the Otter Tail River and the Clearwater River. We resampled sites on the Clearwater River during the summer of 1994 and confirmed its presence at the outlet of Big Buzzle Lake, a tributary to the Clearwater River (Figure 3). Specimens from this collection have been deposited at the Bell Museum of Natural History.

Compared with other large streams in the region, diversity of fishes in the Red River basin is high. The upper Mississippi River (above St. Anthony Falls, Minneapolis) has 69 species (Underhill 1989) of which 62 (74% of species present in the Red River drainage) are shared with the Red River. The Minnesota River has 88 species of which 73 (87%) are shared, and the Missouri River in North Dakota has 65 species (Ryckman 1981) of which 46 (55%) are shared. The ichthyofauna is most closely related to that of the Minnesota River to the south and the upper Mississippi River to the east, quite possibly due to post-glacial dispersal patterns of fishes (Stewart and Lindsey 1983; Underhill 1989; Mandrak and Crossman 1992; Radke 1992).

The Distribution of Stream Fish Species

From examination of distribution patterns of fish species in the Red River basin, the White Sucker, Common Shiner, Fathead Minnow, Creek Chub (*Semotilus atromaculatus*), Black Bullhead (*Ameiurus melas*), Northern Pike, Johnny Darter, Blackside Darter (*Percina maculata*), and Brook

TABLE 2. Fish species reported in surveys of streams and lakes in the Red River of the North basin, United States during 1962-1997.

Taxon	River Drainage																										
	Red	Pembina	Tongue	Park	Forest	Turtle	Goose	Elm	Rush	Maple	Shenenne	Wild Rice, ND	Bois de Sioux	Mustinka	Rabbit	Otter Tail	Pelican	Buffalo	Wild Rice, MN	Sandhill	Red Lake	Clearwater	Snake	Middle	Tamarac	Two	Roseau
Petromyzontidae																											
Ichthyomyzon castaneus	X															X		X			X	X					X
Ichthyomyzon unicuspis	X						X														X	X					
Acipenseridae																											
Acipenser fulvescens																X	X										
Amidae														X													
Amia calva																											
Hiodontidae																											
Hiodon alosoides	X			X		X					X	X				X					X						
Hiodon tergisus	X	X									X	X				X					X						
Salmonidae																											
Coregonus artedii ¹																X		X			X						
Coregonus clupeaformis ¹																X		X			X						
Oncorhynchus mykiss ²											X					X		X			X						
Salmo trutta ²						X										X		X			X						
Salvelinus fontinalis ²																X		X			X						X
Catostomidae																											
Cariodes cyprinus	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Catostomus commersoni	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hypentelium nigricans																											
Ichtiobus bubalus																											
Ichtiobus cyprinellus	X	X			X					X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Moxostoma anisurum	X						X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Moxostoma erythrurum	X			X			X				X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Moxostoma macrolepidotum	X	X					X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Moxostoma valenciennesi	X									X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyprinidae																											
Campostoma anomalum					X																						
Campostoma oligolepis	X																										
Cyprinella spiloptera	X			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Cyprinus carpio ²	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Hybognathus hankinsoni	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Luxilus cornutus	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Macrhybopsis storeriana	X					X																					
Margariscus margarita			X	X														X									X

(Continued)

TABLE 2. Continued.

Taxon	River Drainage																										
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27
<i>Nocomis biguttatus</i>	X				X						X																
<i>Notemigonus chrysoleucas</i>																											
<i>Notropis anogenus</i>	X										X																
<i>Notropis atherinoides</i>	X										X																
<i>Notropis biemini</i>	X										X																
<i>Notropis dorsalis</i>	X										X																
<i>Notropis heterodon</i>											X																
<i>Notropis heterolepis</i>											X																
<i>Notropis hudsonius</i>											X																
<i>Notropis rubellus</i>											X																
<i>Notropis stramineus</i>											X																
<i>Notropis texanus</i>											X																
<i>Notropis volucellus</i>											X																
<i>Phoxinus eos</i>											X																
<i>Phoxinus neogaeus</i>											X																
<i>Pimephales notatus</i>											X																
<i>Pimephales promelas</i>											X																
<i>Platygobio gracilis</i> ²											X																
<i>Rhinichthys atratulus</i>											X																
<i>Rhinichthys cataractae</i>											X																
<i>Semotilus atromaculatus</i>											X																
Ictaluridae											X																
<i>Ameiurus melas</i>											X																
<i>Ameiurus natalis</i>											X																
<i>Ameiurus nebulosus</i>											X																
<i>Ictalurus punctatus</i>											X																
<i>Noturus flavus</i>											X																
<i>Noturus gyrinus</i>											X																
Umbridae											X																
<i>Umbra limi</i>											X																
Esocidae											X																
<i>Esox lucius</i>											X																
<i>Esox masquinongy</i> ²											X																
Cyprinodontidae											X																
<i>Fundulus diaphanus</i>											X																

(Continued)

TABLE 2. Concluded.

Taxon	River Drainage																												
	Red	Pembina	Tongue	Park	Forest	Turtle	Goose	Elm	Rush	Maple	Shenene	Wild Rice, ND	Bois de Sioux	Mustinka	Rabbit	Offet Tail	Pelican	Buffalo	Wild Rice, MN	Sandhill	Red Lake	Clearwater	Snake	Middle	Tamarac	Two	Roseau		
Gadidae																													
<i>Lota lota</i>	X															X	X	X	X	X	X	X							
Percopsidae																													
<i>Percopsis omiscomaycus</i>	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X							X
Percichthyidae																													
<i>Morone chrysops</i> ²	X										X	X		X	X	X													
Centrarchidae																													
<i>Anblophtes rupestris</i>	X	X			X						X	X		X	X	X	X	X	X	X	X	X			X	X	X	X	
<i>Lepomis cyanellus</i>	X									X	X	X		X	X	X	X	X	X	X	X	X			X	X	X	X	
<i>Lepomis gibbosus</i>												X	X												X	X	X	X	
<i>Lepomis humilis</i>											X	X	X		X	X	X	X	X	X	X	X							
<i>Lepomis macrochirus</i>	X						X				X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
<i>Micropterus dolomieu</i>											X	X	X		X	X	X	X	X	X	X	X							
<i>Micropterus salmoides</i>											X	X	X		X	X	X	X	X	X	X	X							
<i>Pomoxis annularis</i>				X						X	X	X	X		X	X	X	X	X	X	X	X							
<i>Pomoxis nigromaculatus</i>	X	X		X	X		X			X	X	X	X		X	X	X	X	X	X	X	X							
Percidae																													
<i>Etheostoma caeruleum</i>						X		X		X	X	X	X		X	X	X	X	X	X	X	X					X		
<i>Etheostoma exile</i>								X		X	X	X	X		X	X	X	X	X	X	X	X							
<i>Etheostoma microperca</i>						X		X		X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
<i>Etheostoma nigrum</i>	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
<i>Perca flavescens</i>	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X							
<i>Percina caprodes</i>	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X							
<i>Percina maculata</i>	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
<i>Percina shumardi</i>	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
<i>Stizostedion canadense</i>	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
<i>Stizostedion vitreum</i>	X	X	X	X	X	X	X	X		X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
Sciaenidae																													
<i>Aplodinotus grunniens</i>	X				X	X	X		X		X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
Cottidae																													
<i>Cottus bairdi</i>															X						X	X							
Gasterosteidae			X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
<i>Culaea inconstans</i>			X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X			X	X	X	X	
River Drainage	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27		
Species Richness	44	32	20	31	31	27	33	14	22	30	56	23	32	17	21	73	49	54	56	29	65	55	19	21	22	31	46		

¹Species found in headwater lakes²Introduced species

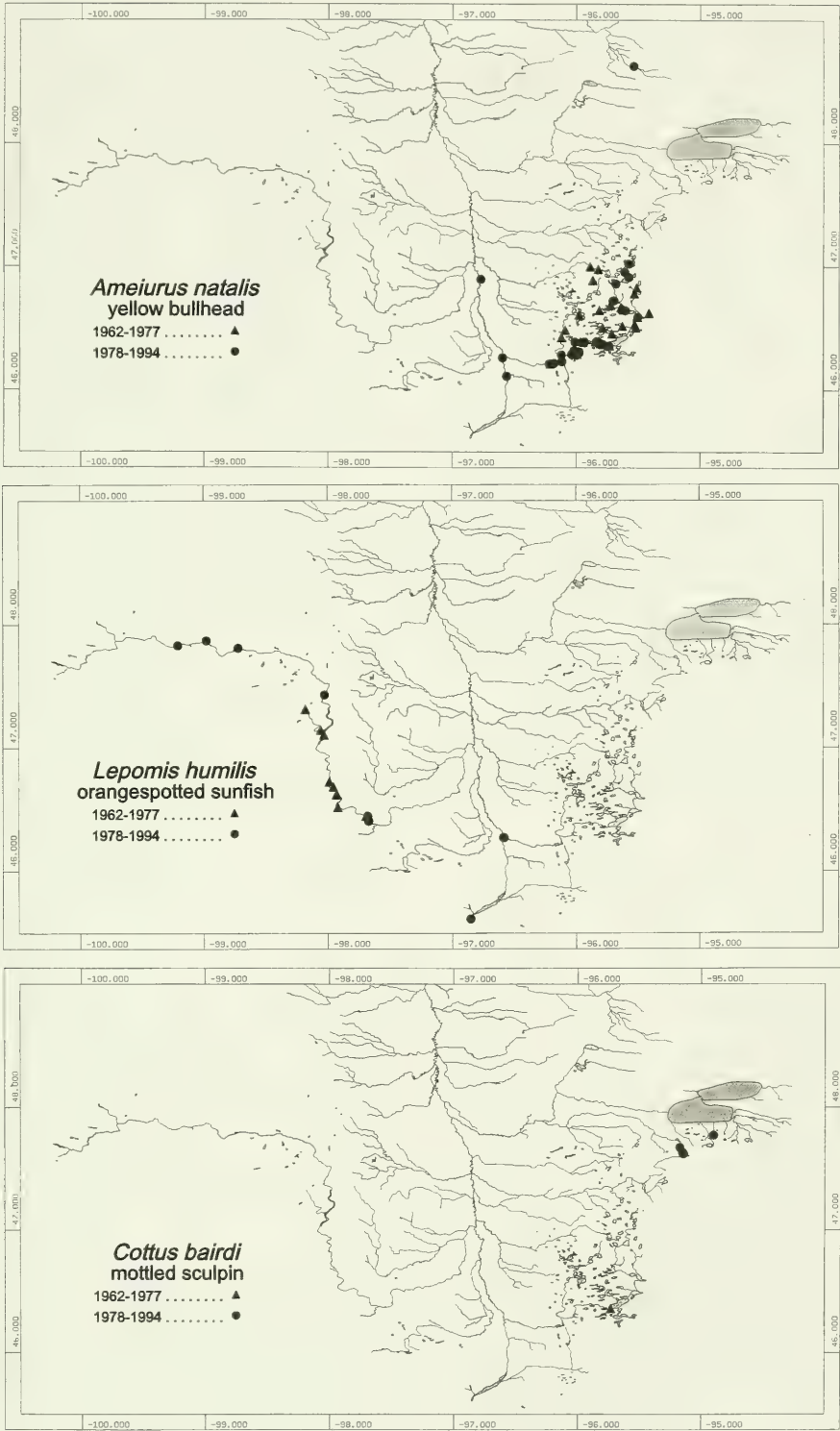


FIGURE 3. Distribution of the Yellow Bullhead, Orangespotted Sunfish, and Mottled Sculpin in the Red River of the North basin in the United States. None of these fishes were collected during the early sampling period (1892–1961).

Stickleback (*Culaea inconstans*) all had relatively widespread distributions. These species were found in headwater and downstream reaches of tributaries in both the eastern and western basin, and in the Red River main stem. Species whose distributions were either mostly or entirely restricted to the eastern half of the Red River basin were the Chestnut Lamprey (*Ichthyomyzon castaneus*), Silver Lamprey (*Ichthyomyzon unicuspis*), Hornyhead Chub (*Nocomis biguttatus*), Pugnose Shiner, Blackchin Shiner (*Notropis heterodon*), Central Mudminnow, and Mottled Sculpin. The Bowfin, Northern Hogsucker, Central Stoneroller (*Campostoma anomalum*), Weed Shiner (*Notropis texanus*), Yellow Bullhead, Rainbow Darter, Least Darter (*Etheostoma microperca*), and Logperch had distributions restricted almost entirely to the Otter Tail and Pelican river drainages. Species whose distributions were either mostly or entirely restricted to the western half of the basin were the Largescale Stoneroller, found only in the Forest River at sites in the glacial Lake Agassiz (Teller and Bluemle 1983) beach ridge (transition) zone (Koel 1997), and the Orangespotted Sunfish, found almost exclusively in the Sheyenne River. The Goldeye (*Hiodon alosoides*), Mooneye (*Hiodon tergisus*), and Silver Chub (*Macrhybopsis storeriana*) have been found only in the Red River main stem or the lower reaches of its tributaries. The Greater Redhorse (*Moxostoma valenciennesi*) has been collected only in the lower reaches of the Otter Tail River, the Red River near Fargo, the lower Maple River, and the Sheyenne River downstream from Valley City.

In the Red River basin, except for the Lake Sturgeon, there have been no extirpations. However, reductions in range for several species were noted by plotting fish species at sites during each of three different time periods (early, middle, and late). The total number and location of sites sampled during each of these periods varied considerably, which makes comparison among them difficult. For example, on the Red River main stem, few sites were sampled during the middle sampling period (1962-1977), but during the late sampling period (1978-1994) it was extensively surveyed (Figure 2). Therefore, by cautiously interpreting distribution patterns, even with the variability in sampling effort between time periods, several notable changes were observed. The Chestnut Lamprey has not been taken in the Sheyenne River since Woolman's early collection in 1892 (Woolman 1896), but it has apparently increased its range southward in the eastern basin. Several collections were made in the Wild Rice River, and a single record exists from the Otter Tail River. Records of the Silver Lamprey are exclusively from the late sampling period, suggesting that the species has recently expanded its range in the basin. The Silver Lamprey has been collected

from the Red, Clearwater, Red Lake, and Buffalo rivers.

Several cyprinids have experienced moderate changes in distribution over the past 105 years. Records from the early sampling period indicate that the Brassy Minnow (*Hybognathus hankinsoni*) once occurred in the Wild Rice River and Shotley Brook, a tributary to Upper Red Lake. Later collections have not included the Brassy Minnow in these or similar locations (Figure 4). Underhill (1958) described this species as one of the most dominant in Minnesota; however, in the Red River basin, Brassy Minnows have been collected only at 3% of stream sites sampled since 1962. Typically, collections have consisted of only one or a few individuals. Harbicht et al. (1988) describe the Brassy Minnow in the Pembina River and other drainages in Manitoba and emphasize its "strangely disjunct (distribution) within the province". The Pearl Dace, while existing in isolated populations in locations such as the headwaters of the South Branch Buffalo, Park, Thief, Roseau, Snake, Middle, and Tamarac rivers, has evidently been extirpated from the headwaters of the Otter Tail and Wild Rice rivers, as it has not been found in these reaches since 1955 (Bell Museum of Natural History, unpublished records 1994). The Hornyhead Chub once existed in the Sheyenne and Maple rivers and was collected at the mouth of the Otter Tail River and Daugherty Creek, a tributary to Lake Traverse; but no collections have been made in those locations in recent years, despite its widespread distribution in several eastern basin streams (Figure 4). The Pugnose Shiner, only rarely collected in the Red River basin, has not occurred in documented collections for over 20 years (Figure 4), however, recent samples from the Otter Tail River have confirmed its continued existence there (Luther Aadland, Minnesota Department of Natural Resources, personal communication 1997). Although the River Shiner no longer occurs in the Red Lake or Sandhill rivers, it has increased its range and currently occurs throughout the Sheyenne River (North Dakota Game and Fish Department reported it at one site above Baldhill Dam). The Blacknose Shiner (*Notropis heterolepis*) has had its distribution in the Sheyenne River reduced to only the spring-fed streams at the Mirror Pool Wildlife Management Area.

For the Brown Bullhead, overall occurrence at sites was reduced by 10% from the middle to the late sampling period. The Banded Killifish (*Fundulus diaphanus*) has not been collected from the Sheyenne River since 1892. The Iowa Darter (*Etheostoma exile*) has not been collected in the Park and Tamarac rivers since the early sampling period, and the current distribution of the River Darter (*Percina shumardi*) appears to be restricted to the Thief, Middle, and Roseau rivers.

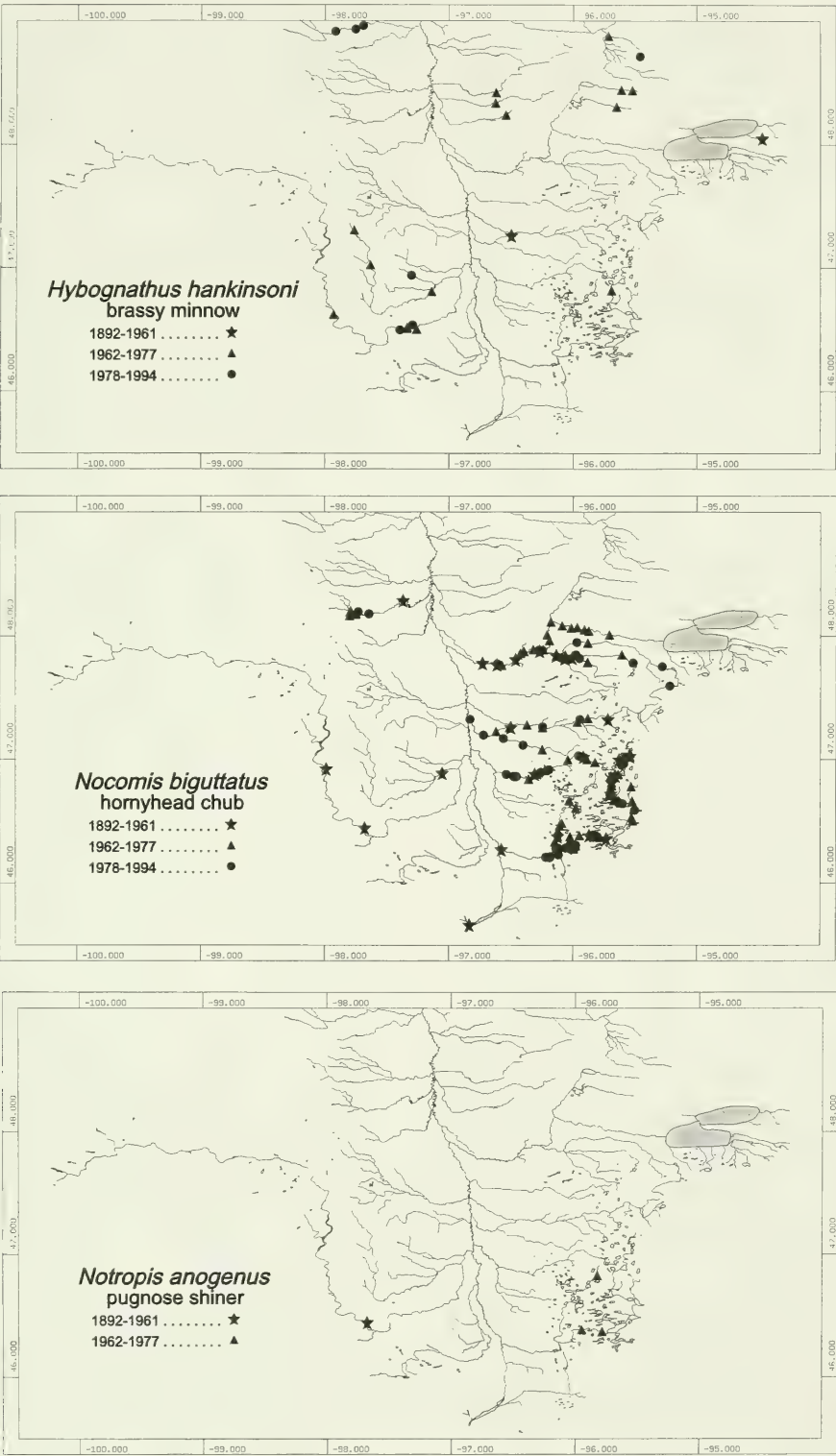


FIGURE 4. Distribution of the Brassy Minnow, Hornyhead Chub, and Pugnose Shiner in the Red River of the North basin in the United States.

Species diversity was highest in the Otter Tail and Red Lake river drainages (73 and 65 species, respectively) in the eastern basin and the Sheyenne River drainage (56 species) in the western basin; these are streams that have a wide range of habitats for stream fishes and have a relatively high, stable hydrological regime. However, we found that most of the streams in the Red River basin have one or several unique fish species. The Forest River is an excellent example. A relatively small stream with a length of only about 120 km, it supports the only documented largescale Stoneroller population in the entire Hudson Bay drainage basin, and the only remaining population of Hornyhead Chubs in North Dakota. Hornyhead Chub are known to be intolerant of mud or silt substrates and turbid waters (Dalton 1989) often resulting from agricultural practices (Trautman 1957; Smith 1979). The upper reaches of the Tongue River, a tributary to the Pembina River, have relatively isolated populations of Pearl Dace and Finescale Dace. In the western basin the Northern Redbelly Dace (*Phoxinus eos*) only occurs in the Rush River and in spring-fed creeks in the Mirror Pool Wildlife Management Area, Sheyenne River. The only occurrences of Banded Killifish in the western basin is in the lower reaches of the Park and Turtle rivers where waters are high in specific conductance (average for the Turtle River is 3800 $\mu\text{S}/\text{cm}$); the species is known to be salinity tolerant (Houston 1990).

Overall, it appears that most fish species in the basin have been resilient in the face of a multitude of changes to the Red River ecosystem during the past century, although there are several examples of species which have had substantial reductions in range. The distributions of many species may have been influenced directly by anthropogenic disturbances such as barriers to migration due to dam construction, stream channelization, or sedimentation, while others may have been indirectly influenced through increased predation or competition with species which are not effected by these disturbances. The Lake Sturgeon was completely extirpated, probably due to a lack of migration corridors (Houston 1987); at least 300 dams of various sizes have been constructed in the basin (Stoner et al. 1993). Limited distribution and abundance of fishes due to lack of reproductive success caused by high levels of salinity was described by Koel (1993) and Koel and Peterka (1995) for another regional system, the Devils Lake chain of lakes in North Dakota, and the optimal chemical and hydrological conditions for Red River fishes have been described by Koel (1997). Fish distributions are best explained by several important environmental variables simultaneously (multivariate analysis). The coefficient of variation of mean monthly discharge, average low discharge in May, average annual discharge, specific

conductance, total hardness, and residue were determined to be the most important physiochemical correlates of fish assemblage structure in streams of the Red River basin. In general, reaches with high species diversity were characterized by waters with high discharge and low flow variability, specific conductivity, hardness, and residue (Koel 1997).

Acknowledgments

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Author's Note

A detailed annotated list and site-specific distribution maps for all Red River fishes has been provided by Peterka and Koel (1996) and Koel (1997). The results of this research are also available on the world wide web at <http://www.npwrc.usgs.gov/resource/1998/norbasin/norbasin.htm> [Koel, Todd Marvin. 1997. Distribution of fishes in the Red River of the North basin on multivariate environmental gradients. Ph.D. thesis, North Dakota State University, Fargo, North Dakota. Northern Prairie Wildlife Research Center Home Page (Version 03June98)].

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Red Alder, *Alnus rubra*, as a Potential Mitigating Factor for Wildlife Habitat Following Clearcut Logging in Southeastern Alaska

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Within-stand variation in understory species composition and biomass was studied in 16 even-aged stands of mixed Red Alder - Sitka Spruce - Western Hemlock (*Alnus rubra* - *Picea sitchensis* - *Tsuga heterophylla*) forest. The sites were upland sites, and the stands were 28-39 years old. We compared understory within three categories of microsite types: Red Alder-dominated, conifer-dominated, and mixed alder-conifer. Biomass of forbs and ferns differed significantly ($P < 0.05$) between microsite types, being greatest in alder microsites, least in conifer microsites, and intermediate in mixed alder-conifer microsites for all of the following: *Circaea alpina*, *Galium triflorum*, *Tiarella trifoliata*, *Viola glabella*, *Athyrium filix-femina*, *Gymnocarpium dryopteris*, *Thelypteris phegopteris*, total forbs, total ferns, and total herbs. Shrub biomass also was greatest in alder microsites but was least in mixed microsites and intermediate in conifer microsites ($P < 0.05$ for *Rubus spectabilis* leaves and total shrub leaves). The greater shrub biomass in conifer than mixed microsites resulted from several large patches of poor tree regeneration within 7 of the 16 stands; the other 9 stands had very low understory biomass in their conifer microsites, which is consistent with published studies of understory dynamics in even-aged stands of the region. The results illustrate two important conclusions regarding current understanding of secondary succession following clearcutting in southeastern Alaska: (1) inclusion of Red Alder in the regenerating stand may result in much greater understory biomass than occurs in pure conifer stands; and (2) extrapolation of data from small, uniform, fully-stocked research stands to the landscape level may underestimate understory biomass from poorly stocked patches. Both conclusions have important implications for wildlife habitat in terms of understory vegetation for food and cover. The potential of Red Alder as a mitigating factor for wildlife habitat following clearcutting in the region needs additional study of disturbance-site-understory interactions. Our results, however, indicate that an understory-exclusionary stage of secondary succession is not necessarily the only successional pathway following clearcutting in southeastern Alaska.

Key Words: Red Alder, *Alnus rubra*, Sitka Spruce, *Picea sitchensis*, Western Hemlock, *Tsuga heterophylla*, secondary succession, understory, biomass, forests.

Land-management practices for timber production and for wildlife habitat often are in conflict in southeastern Alaska. Timber managers prefer clearcut logging as the timber harvest technique for a variety of silvicultural reasons (Ruth and Harris 1979): (1) the old-growth Western Hemlock-Sitka Spruce (*Tsuga heterophylla* - *Picea sitchensis*) forests have much timber "defect" (dead or dying trunks and limbs) that is best removed from the new stand; (2) maximum opening of the forest canopy provides maximum light and soil temperatures for maximum productivity of regenerating trees; (3) the more commercially valuable Sitka Spruce is less shade tolerant than is the less valuable Western Hemlock; (4) physical damage of the residual or regenerating stand, eventually leading to disease, is minimized; and (5) logging costs per unit of timber harvested are least with the clearcut method. Natural overstocking of the regenerating stand is a common silvicultural problem (Harris and Farr 1974).

Clearcut logging, however, is recognized as having broadly negative consequences for wildlife habitat in southeastern Alaska (Wallmo and Schoen 1980; Schoen et al. 1981, 1988; Samson et al. 1989; Hanley 1993). Dense conifer regeneration and

canopy closure result in a very depauperate understory from about 25-150 years stand age (Alaback 1982, 1984a, 1984b). Silvicultural thinnings of the regenerating stand promote tree growth but have insignificant effects on understory, with widely spaced thinnings resulting in a second layer of Western Hemlock regeneration (Deal and Farr 1994). Recent concern about such negative effects on understory and wildlife habitat have prompted new research into selective logging systems (uneven-aged management) with helicopters. Helicopter logging is very expensive, however, and is not likely to be cost-effective on all sites. Selective logging without helicopters is prohibitively costly in the steep, wet terrain, where roading costs are high and damage to residual trees by cable yarding is great.

In a study of riparian forests, Hanley and Hoel (1996) recently reported that understory biomass and species richness of 40-year-old Red Alder (*Alnus rubra*) stands did not differ from that of either old-growth Sitka Spruce riparian stands or old-growth Western Hemlock-Sitka Spruce upland stands. Such productive and diverse understory was contrary to expectations based on stand age-understory relations in the region (also see Deal 1997). Hanley (1996)

subsequently studied small mammal densities and body weights in upland, even-aged, Red Alder - conifer forests in comparison to upland, old-growth forests and found very few significant differences: Densities of Common Shrew (*Sorex cinereus*) and body weights of Sitka Mouse (*Peromyscus keeni sitkensis*) were greater in the even-aged than old-growth stands during the second of two trapping periods; and Long-tailed Vole (*Microtus longicaudus*) was more commonly associated with Red Alder microsites than with conifer microsites within the even-aged stands.

The purpose of our study was to describe quantitatively the understories of upland, even-aged, Red Alder - conifer forests to gain a better understanding of their biomass and species composition. Such stands apparently differ significantly from expectations based on stand-age relations in the region (Alaback 1982), and may offer greater prospect for wildlife habitat than has heretofore been recognized. Alaback (1982, 1984a, 1984b) deliberately excluded Red Alder patches from his chronosequence studies, because modern logging methods (high-lead cable yarding) minimize soil disturbance and the subsequent presence of Red Alder. Although Red Alder is a common tree along active channel courses in riparian forests, its presence in upland forests of the region is very minimal without extensive soil disturbance from log skidding or road construction.

We were especially interested in within-stand variation between conifer-dominated microsites (the "typical" successional sequence) and Red Alder-dominated microsites.

Methods

We sampled 16 Red Alder - conifer, even-aged stands scattered throughout Tenakee Inlet on Chichagof Island, Alaska (57° 45' N, 135°-136° W) within 500 meters of the beach. Such stands regenerated in the early years of clearcutting shortly after the construction of pulp mills in Sitka and Ketchikan in the 1950s. Large amounts of Red Alder resulted from high degrees of soil disturbance in the early logging methods involving tractor skidding and A-frame yarding of logs (Ruth and Harris 1979). Red Alder establishment was greatly reduced when logging methods changed to high-lead yarding of logs with minimal soil disturbance. Consequently, stands with an extensive Red Alder component tend to be concentrated within a relatively narrow range of ages in southeastern Alaska. Our stands ranged in age from 28-39 years and in size from 10-100 ha.

Field reconnaissance was conducted during June 1997, and included site selection for sampling, aging of each stand by counting growth rings from cores of 10 Red Alders taken at near-ground level, and understory plant collections for species identification and preliminary size-weight estimates. Sampling was

conducted throughout July and August, when understory biomass is at its peak and relatively constant in amount (Hanley and McKendrick 1985). We sampled both understory and overstory on the same transects within each stand: 10 parallel transects, each 200 m long and running perpendicular to the beach, spaced 15 m apart (providing a sample area of about 3 ha per stand).

Understory biomass was sampled at 10-m intervals along each transect (200 stations per stand) within a 0.1-m² quadrat (0.2 × 0.5 m). We chose to sample many small quadrats rather than fewer large quadrats (e.g., 1.0-m²) to obtain a large number of samples and to spread those samples over a large area. We sampled only vascular species and did not include mosses, lichens, and liverworts. Species-specific biomass of all herbs and shrub leaves within each quadrat was estimated by the plant-unit method (Parker et al. 1993): regression equations were developed between oven-dry weight (100°C) and estimated weight for each species; accuracy and precision were checked frequently throughout the two-month sampling period (the total data base consisting of 982 paired measures). Shrub stems were clipped at ground level, stripped of leaves, and weighed in the field with Pesola spring scales; representative samples were oven-dried for dry-matter coefficients. Tree seedlings (<2.5 cm diameter at breast height) were harvested, oven-dried, and weighed. An overstory category type ("conifer," "alder," or "mixed") was assigned to each quadrat on the basis of overstory within a 5-m radius of the quadrat center: canopy coverage ≥ 70% relative composition was required for categorizing as predominately "conifer" or "alder," while anything less was "mixed." Mean values for all variables were calculated for each stand for each of the three overstory types.

Every fourth quadrat was used as a point center for the point-center-quarter method (Cottam and Curtis 1956) of sampling forest overstory (50 points per stand) for density, basal area, and species composition. These data were used for descriptive purposes only and were not used in analysis of the understory data.

Statistical analysis of the understory data consisted of species-specific comparisons of "conifer," "alder," and "mixed" microsites across all 16 stands in randomized-block analysis of variance tests (Zar 1974) with stands as blocks and microsites as treatments. Multiple comparisons were tested for significance with Sheffé's test (Wilkinson et al. 1992). An alpha level of 0.05 was the criterion of statistical significance in all analyses.

Results and Discussion

The stands were predominately conifer with a substantial Red Alder component: 35 percent Sitka

Spruce, 21 percent Western Hemlock, and 44 percent Red Alder, on a basal area basis (Table 1). Variation across all 16 stands was relatively low with standard errors ranging from 3–19 percent of their means (dbh of Red Alder, and basal area of Sitka Spruce, respectively). The differences between microsite types, however, were great: the alder sites were 68 percent Red Alder (basal area), while the conifer sites were 60 percent Sitka Spruce and 29 percent Western Hemlock. Conifer basal area within the conifer microsites was similar to that of even-aged conifer stands of similar age throughout southeastern Alaska (Deal and Farr 1994).

Major differences between microsite types occurred in understory biomass, especially among the herbs (Table 2). All of the following had greatest biomass in the alder microsites and least biomass in the conifer microsites: Enchanter's Nightshade (*Circaea alpina*), Sweet-scented Bedstraw (*Galium triflorum*), Foamflower (*Tiarella trifoliata*), Stream Violet (*Viola glabella*), Lady Fern (*Athyrium filix-femina*), Oak Fern (*Gymnocarpium dryopteris*), Beech Fern (*Thelypteris phegopteris*), total forbs, total ferns, and total herbs. It is the herb component that is most difficult to maintain through secondary succession of even-aged stands following clearcutting in southeastern Alaska (Alaback 1982; Hanley 1993).

The shrub component also differed between microsite types (Table 2), but its pattern was not the same as that of the herbs: While biomass was greatest in alder microsites, it was least in mixed, rather than conifer microsites, and statistically significant differences occurred only for Salmonberry (*Rubus spectabilis*) leaves and total shrub leaves. Because the shrub component far outweighed the herb component, the pattern for total understory biomass followed the shrub pattern rather than the herb pattern.

The strong showing of shrubs in the conifer microsite type was surprising. We had expected the mixed type to form a transition between alder and conifer. Closer inspection of the within-stand data, however, revealed that the conifer-type means were strongly influenced by a few patches of poor tree regeneration, where the shrubs were consequently very abundant. Such patches occurred in 7 of the 16 stands; mean total understory biomass of the conifer type in the other 9 stands was 5.46 ± 1.42 (SE) g/m², which is similar to published values for similar aged conifer stands in the region (Alaback 1982).

Current understanding of vegetation dynamics during secondary succession following clearcutting in southeastern Alaska is based on results from research plots that were carefully selected to be relatively homogeneous and representative of site conditions (e.g., Alaback 1982; Deal and Farr 1994). Minimizing within-stand variance is an important and necessary objective of studies of between-stand differences. However, our study illustrates two very important consequences of extrapolating such data to the landscape level: (1) the exclusion of Red Alder patches from the chronosequence yields a very different pattern of secondary succession than is necessarily the case; and (2) the exclusion of patches of poor regeneration within even-aged conifer stands yields a pattern of understory biomass more depauperate than may be the case over a larger area (e.g., the entire stand).

Both of those considerations have important consequences for understory vegetation and wildlife habitat. Although our stands were still relatively young, the understory differences between alder and conifer microsites should be expected to persist for some additional time into the future. Furthermore, we expect that as the Red Alder eventually dies and is replaced by conifers, the resulting conifer stand

TABLE 1. Overstory characteristics of 16 Red Alder-conifer stands in Tenakee Inlet, Alaska (mean \pm standard error, range).

Grouping/species	Density (stems/ha)	DBH ^a (cm)	Basal Area (m ² /ha)
Entire stands			
Red Alder	426 \pm 57, 135-1029	23.0 \pm 0.7, 18-28	19.0 \pm 2.2, 6-36
Sitka Spruce	365 \pm 32, 123-645	18.4 \pm 1.3, 15-26	15.0 \pm 2.8, 2-39
Western Hemlock	267 \pm 45, 39-752	16.8 \pm 1.0, 11-24	9.1 \pm 1.6, 1-25
Alder Microsites			
Red Alder	799 \pm 78, 354-1619	22.5 \pm 0.8, 17-29	31.5 \pm 1.9, 15-47
Sitka Spruce	141 \pm 25, 69-489	15.8 \pm 0.9, 9-22	6.0 \pm 1.2, 1-20
Western Hemlock	55 \pm 18, 9-285	15.0 \pm 1.2, 9-22	8.6 \pm 4.5, 1-42
Conifer Microsites			
Red Alder	106 \pm 13, 0-174	21.5 \pm 1.0, 17-29	4.9 \pm 0.8, 0-11
Sitka Spruce	598 \pm 56, 315-1111	20.9 \pm 0.8, 12-32	27.3 \pm 4.1, 12-77
Western Hemlock	547 \pm 105, 160-1793	17.6 \pm 1.4, 10-24	13.1 \pm 1.9, 4-31
Mixed Microsites			
Red Alder	390 \pm 38, 116-645	25.4 \pm 1.0, 18-35	20.9 \pm 1.9, 8-32
Sitka Spruce	356 \pm 33, 71-1072	18.7 \pm 1.3, 7-28	12.6 \pm 3.0, 1-49
Western Hemlock	201 \pm 57, 7-570	16.5 \pm 1.8, 6-30	6.2 \pm 2.1, 0-32

^aDiameter at breast height

TABLE 2. Understory biomass (g/m^2 , mean \pm standard error) of "alder," "conifer," and "mixed" microsite types across 16 Red Alder-conifer stands in Tenakee Inlet, Alaska. Values with different superscripts within a row differ at the alpha level of 0.05, randomized block analysis of variance followed by Sheffé's multiple comparison test. t = trace = <0.005 . Total number of 0.1-m^2 quadrats sampled in each of the microsite types: alder 1283, conifer 1281, mixed 636. L = leaves; S = stems.

Class/species	Alder	Conifer	Mixed
Forbs			
Baneberry <i>Actaea rubra</i>	0.04 ± 0.03	0 ± 0	0 ± 0
Enchanter's Nightshade <i>Circaea alpina</i>	0.95 ± 0.26^b	0.10 ± 0.05^a	0.29 ± 0.12^a
Fern-leaf Goldthread <i>Coptis asplenifolia</i>	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
Bunchberry <i>Cornus canadensis</i>	0.01 ± 0.01	0.05 ± 0.03	0.01 ± 0.01
Sweet-scented Bedstraw <i>Galium triflorum</i>	0.04 ± 0.02^b	$t \pm t^a$	$t \pm t^{ab}$
Cow Parsnip <i>Heracleum lanatum</i>	0.89 ± 0.43	0 ± 0	0.48 ± 0.30
Skunkcabbage <i>Lysichiton americanum</i>	0.10 ± 0.10	0.17 ± 0.13	0.01 ± 0.01
False Lily-of-the-valley <i>Maianthemum dilatatum</i>	0.41 ± 0.14	0.14 ± 0.02	0.25 ± 0.06
Five-stemmed Mitrewort <i>Mitella pentandra</i>	0.01 ± 0.01	0 ± 0	0.01 ± 0.01
Rattlesnake-root <i>Prenanthes alata</i>	0.02 ± 0.01	0 ± 0	0 ± 0
Five-leaved Bramble <i>Rubus pedatus</i>	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
Clasping Twisted-stalk <i>Streptopus amplexifolius</i>	0.47 ± 0.19	0.43 ± 0.15	1.10 ± 0.45
Crisp Sandwort <i>Stellaria crispa</i>	0.02 ± 0.02	0 ± 0	0 ± 0
Foamflower <i>Tiarella trifoliata</i>	1.22 ± 0.28^b	0.29 ± 0.06^a	0.52 ± 0.14^a
Stream Violet <i>Viola glabella</i>	0.08 ± 0.02^c	$t \pm t^a$	0.01 ± 0.01^b
Total Forbs	4.29 ± 0.57^c	1.24 ± 0.25^a	2.71 ± 0.53^b
Ferns			
Maidenhair Fern <i>Adiantum pedatum</i>	0.04 ± 0.03	0 ± 0	0 ± 0
Lady Fern <i>Athyrium filix-femina</i>	5.65 ± 0.90^b	0.75 ± 0.56^a	2.48 ± 0.78^{ab}
Deer Fern <i>Blechnum spicant</i>	0.01 ± 0.01	0.01 ± 0.01	0.03 ± 0.03
Shield Fern <i>Dryopteris austriaca</i>	1.30 ± 0.19	1.06 ± 0.20	1.85 ± 0.35
Oak Fern <i>Gymnocarpium dryopteris</i>	4.07 ± 0.55^c	0.75 ± 0.11^a	2.19 ± 0.38^b
Beech Fern <i>Thelypteris phegopteris</i>	0.81 ± 0.23^c	0.09 ± 0.05^a	0.10 ± 0.04^b
Total Ferns	11.88 ± 1.18^c	2.65 ± 0.79^a	6.66 ± 1.11^b
Graminoids			
Merten's Sedge <i>Carex mertensii</i>	0.01 ± 0.01	0 ± 0	0 ± 0
Small-flowered Woodrush <i>Luzula parviflora</i>	0.01 ± 0.01	0.02 ± 0.02	0 ± 0
Nodding Trisetum <i>Trisetum cernuum</i>	0.05 ± 0.04	$t \pm t$	0 ± 0
Total Graminoids	0.07 ± 0.04	0.02 ± 0.02	0 ± 0
Total Herbs	16.23 ± 1.35^c	3.91 ± 0.83^a	9.37 ± 1.38^b
Shrubs			
Rusty Menziesia <i>Menziesia ferruginea</i> (L)	$t \pm t$	0.07 ± 0.07	$t \pm t$
<i>Menziesia ferruginea</i> (S)	$t \pm t$	0.61 ± 0.61	0.05 ± 0.04
Devilsclub <i>Oplopanax horridum</i> (L)	4.37 ± 1.81	1.82 ± 1.41	0.52 ± 0.42
<i>Oplopanax horridum</i> (S)	19.32 ± 7.66	19.45 ± 11.90	2.85 ± 2.65
Stink Current <i>Ribes bracteosum</i> (L)	0.54 ± 0.23	0.10 ± 0.10	0.01 ± 0.01
<i>Ribes bracteosum</i> (S)	1.67 ± 0.92	0.14 ± 0.13	0.01 ± 0.01
Salmonberry <i>Rubus spectabilis</i> (L)	2.23 ± 0.91^b	0.85 ± 0.34^{ab}	0.27 ± 0.12^a
<i>Rubus spectabilis</i> (S)	6.38 ± 2.74	5.42 ± 2.11	0.61 ± 0.27
Red Elderberry <i>Sambucus racemosa</i> (L)	0.23 ± 0.20	0.02 ± 0.02	0.53 ± 0.43
<i>Sambucus racemosa</i> (S)	0.54 ± 0.47	0.03 ± 0.03	2.37 ± 2.29
Early Blueberry <i>Vaccinium ovalifolium</i> (L)	0.50 ± 0.40	1.31 ± 0.99	0.16 ± 0.09
<i>Vaccinium ovalifolium</i> (S)	0.98 ± 0.85	5.77 ± 3.48	0.70 ± 0.45
Total Shrub Leaf	7.87 ± 2.19^b	4.18 ± 1.60^{ab}	1.49 ± 0.64^a
Total Shrub Stem	28.88 ± 8.38	31.41 ± 13.18	6.59 ± 3.81

Continued

TABLE 2. *Concluded*

Class/species	Alder	Conifer	Mixed
Tree Seedlings			
Sitka Spruce <i>Picea sitchensis</i> (L)	0.69 ± 0.34	0 ± 0	0 ± 0
<i>Picea sitchensis</i> (S)	1.34 ± 0.74	0 ± 0	0 ± 0
Western Hemlock <i>Tsuga heterophylla</i> (L)	0.73 ± 0.73	0.11 ± 0.11	0 ± 0
<i>Tsuga heterophylla</i> (S)	1.25 ± 1.25	0.21 ± 0.20	0 ± 0
Total Tree Seedlings	4.01 ± 2.12	0.33 ± 0.31	0 ± 0
Total Vascular Biomass	57.00 ± 11.10 ^b	39.83 ± 14.77 ^{ab}	17.54 ± 5.46 ^a

will have a much more structurally diverse character than that normally associated with even-aged conifer stands. Structural diversity of the overstory is one of the factors believed to be important in maintaining understory in coastal coniferous forests (Franklin et al. 1981; Spies and Franklin 1991). Equally important for wildlife is the strong herb component of the alder microsites. Finally, the patches of poor tree regeneration result in delayed timing of the conifer chronosequence and add to the total understory biomass of the site as a whole.

The significance of these patterns in herb composition and total understory biomass is evident in the presence of abundant and productive populations of Common Shrew, Sitka Mouse, and Long-tailed Vole in mixed Red Alder - conifer stands of southeastern Alaska (Hanley 1996), as well as those of many other species of small mammals and birds reported elsewhere (McComb 1994). Both the abundance of understory (biomass) and its nutritional quality are important. This can be illustrated by a simple conversion of understory biomass to the number of adult, female, Black-tailed Deer (*Odocoileus hemionus sitkensis*) that could be supported at maintenance levels by the food bases of the microsite types (Hanley and Rogers 1989). For simplicity, we base the calculations on digestible energy and assume the following digestible dry-matter values, calculated at the forage-class level from species-specific data for plants collected in August (Hanley and McKendrick 1983): Forbs and ferns, 61.7%; graminoids, 52.8%; shrub leaves, 48.0%; conifer leaves, 29.9%. The resulting summer carrying capacities (deer days use per hectare) from the Hanley and Rogers (1989) algorithm follow: alder microsites, 202; mixed microsites, 73; conifer microsites (all 16 stands), 45; and conifer microsites excluding the seven stands with large patches of poor regeneration, 7. The greater nutritional value of forbs than shrubs, combined with the greater biomass of forbs in the mixed than conifer microsites, results in the greater carrying capacity of mixed than conifer sites despite their lesser total understory biomass.

We believe that these results are important in highlighting a potential value of Red Alder as a miti-

gating factor for wildlife habitat following clearcut logging in southeastern Alaska. Red Alder has been considered a weed species by timber managers concerned about its competition with conifers in regenerating stands (Ruth and Harris 1979), yet it might be viewed quite differently if it can help reduce the loss of wildlife habitat now associated with clearcutting in the region. Red Alder can be included in even-aged stands perhaps as simply as by incorporating a certain amount of soil disturbance into the logging operation (Ruth and Harris 1979). However, the necessity for including Red Alder *per se* is not yet clear: Is Red Alder a causative factor in the environment for the understory vegetation; or is its presence simply correlated with that of the understory as a consequence of the initial site disturbance? Much more needs to be learned about ecological interactions between Red Alder, site factors (including disturbance), and understory vegetation before we can design optimal silvicultural applications and prescriptions. That will require additional research into both alder-understory relations and alder-conifer relations (Newton and Cole 1994). Our study is simply a first step that indicates that the potential is there and that an understory-exclusionary stage of secondary succession is not necessarily the only successional pathway following clearcutting in southeastern Alaska.

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Nest Defense by the Non-indigenous Fish, the Round Goby, *Neogobius melanostomus* (Gobiidae), on a Shipwreck in Western Lake Erie

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This is the first documentation of nest defense by a male Round Goby (a non-indigenous fish) on an exposed nest in North America. Our observation of Round Goby nesting behaviour on a shipwreck in the western basin of Lake Erie using a video camera indicate that these fish spawn at much greater depths (7–11 m) than previously reported (≤ 2 m). Of species that approached the nest (Rock Bass, *Ambloplites rupestris*; Smallmouth Bass, *Micropterus dolomieu*; Yellow Perch, *Perca flavescens*; Logperch, *Percina caprodes*; Round Gobies, *Neogobius melanostomus*), most behavioural interactions occurred between the guarding male and other Round Gobies. During 12 min of observation, there were 63 instances in which a Round Goby approached the nest and in four cases, intruders fed on eggs at the periphery of the nest. In response, the guarding male approached (34 times), chased (18 times) and hit (4 times) Round Goby intruders. Response by the resident goby to the presence of Rock Bass (one swam by and seven approached) resulted in six approaches, four chases and one hit. The resident male responded to juvenile Smallmouth Bass (three swam by and seven approached) only once by approaching the intruder. The guarding male did not respond to either Logperch or Yellow Perch, but too few events were observed to suggest that the absence of a response by a male was typical. We anticipate that recruitment of Round Gobies will increase substantially in Lake Erie owing to the presence of artificial reefs (shipwrecks) and the ability of guarding males to defend nests effectively.

Key Words: Round Goby, *Neogobius melanostomus*, non-indigenous fish, nest defense, shipwrecks, Lake Erie.

Two bottom-dwelling fishes, *Neogobius melanostomus* (Round Goby) and *Proterorhinus marmoratus* (Tubenose Goby), of the family Gobiidae and native to the Black and Caspian seas, were first discovered in the St. Clair River in 1990 (Crossman et al. 1992; Jude et al. 1992). Although the smaller Tubenose Goby is limited to the St. Clair River, Lake St. Clair, Detroit River, and sites along the north shore of western Lake Erie (Corkum, personal observation), the Round Goby has dispersed rapidly to all five Great Lakes (Jude 1997). Reasons for the proliferation of Round Gobies include the ability of larger (total length > 7 cm) fish to eat readily available Zebra Mussels (*Dreissena polymorpha*) (Ray and Corkum 1997) and the habit of Round Gobies to spawn repeatedly (every 3 to 4 weeks) throughout spring and summer (Charlebois et al. 1997). In the Detroit River, Round Gobies were observed to spawn from early June until August (MacInnis 1997). Round Goby males maintain and defend nests of eggs deposited by several females (Miller 1984; MacInnis 1997).

The persistence of a species depends on the existence of local populations (Hanski and Simberloff 1997). In the summer of 1997, we observed spatially isolated reproducing populations of Round Gobies on shipwrecks (Conemaugh, George Stone, Northern Indiana and Wilcox) in western Lake Erie at greater depths (7–11 m) than typically reported (0.2 to 2 m) (Charlebois et al. 1997; MacInnis 1997). There are

4670 shipwrecks in Canadian waters of Lakes Erie and Huron including more than 200 wrecks in the Pelee Passage of Lake Erie (Kohl 1995). Since Round Gobies prefer rocky habitats (personal observation), complex structures such as shipwrecks and natural reefs (rocky islands within a matrix of soft sediments) are likely locations for breeding populations. Shipwrecks may be particularly attractive to Round Gobies if predation risk (to eggs, juveniles, and adults) is reduced. The increased habitat complexity (shelter) and availability of food (Zebra Mussels) on shipwrecks provides ideal habitat for Round Gobies.

In this paper, we document the defense by a male Round Goby of an exposed nest on a shipwreck, the schooner, *M. I. Wilcox*, in western Lake Erie. This is the first documentation of nest defense by Round Gobies in North America.

Methods

Observations were conducted on the shipwreck, the *M. I. Wilcox* (41° 59' N, 82° 57' W) about 0.6 km offshore of Colchester, Ontario, in western Lake Erie. The schooner, 42.7 m long, sank in 1906 in water 7 m deep. ErieQuest, a marine heritage organization, and the Canadian Coast Guard provided a mooring buoy at this and other shipwrecks for public exploration.

Using SCUBA, R. G. Wickett identified a nest defended by a male Round Goby on 19 August 1997. To expose the nest, the top covering, an iron pulley,

was removed and subsequent interactions between the guarding male and other fishes were videotaped using a video camera recorder (Sony® Hi8 model CCD-TR910) and underwater Amphibico® housing unit. The video camera was placed on a tripod and the SCUBA diver withdrew from the immediate area. Behavioural interactions on the exposed nest were recorded for 11 min 43 sec (7:32 to 7:44 p.m. EDT) before the battery ran low. The cover of the nest was then replaced and all recording gear was removed.

Videotape was analysed by noting, in order of degree of threat, the number of times individuals of each fish species (intruders) swam by the nest, approached the nest, or ate eggs. In addition, the number of times and types of response (approach, chase, hit), by the resident male were recorded. An "approach" was an orientation and slow movement or advance toward another fish. A "chase" was a quick movement or dart toward another fish. Both "approach" and "chase" resulted in the intruder moving away from the nest. A "hit" occurred when the resident round goby butted or forcibly touched another fish. Figure 1 illustrates a "hit" by the guarding Round Goby against a Rock Bass (*Ambloplites rupestris*). Occasionally, an approach was followed by a chase so these behaviours were not always independent. A hit was always preceded by a chase. Since parental males are distinctive in colour (charcoal black with a white or an orange line along the edge of the fins), the resident Round Goby was easily identified and distinguished from other fishes. Fish lengths were estimated using a known width of an object in the field of view.

Results and Discussion

The Round Goby nest was found on the keelson, a long wooden beam lying above the keel of the schooner. The schooner lies collapsed but upright on the lake bottom. A steel pulley formed the top of the nest and the floor of the nest was a shallow hollow

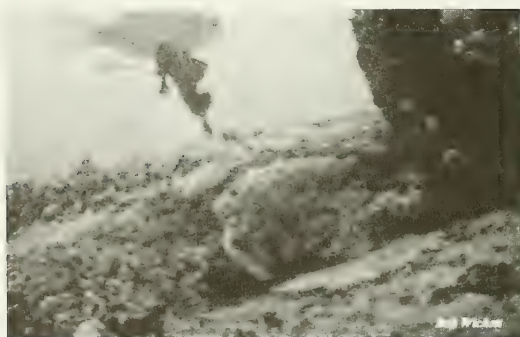


FIGURE 1. A "hit" by a nest-guarding Round Goby against a Rock Bass from a videotape taken by Bob Wickett (see text for details).

in the wooden beam. Before the nest was exposed, the snout of the guarding male was observed extending out of the single opening. Typically, the guarding male positions himself with his head at the entrance of the nest and nips at intruders. In response to the presence of small (about 5 cm in total length) Round Gobies that approached the area, the breeding male (total length: 11.6 cm) darted forward so that its body extended out of the nest to a point where the fused pelvic fin joined the body.

Once the top of the nest was pulled back and placed upright at one end of the nest, the male left the nest, swam < 30 cm away and returned within 19 sec. During the 12-min observation period, the male would often position himself in the hollow or groove of the nest on top of the eggs, moving back and forth within the groove. The male also would dart haphazardly to different locations about the nest.

The oval eggs were packed together in a single layer on the floor of the nest, covering an area of about 35.5 cm². In gobiids, eggs are usually attached to the ceiling of nests. The "hanging" position and ovoid egg shape presumably aid in nest maintenance as the male can move the water around egg surfaces so that sediment particles can be easily shed (Miller 1984). Our observations of eggs on the floor of this nest and others on another shipwreck, the *Conemaugh* (41° 55' N; 82° 31' W), located off-shore of Point Pelee, suggest that Round Gobies are more flexible in the positioning of eggs in nests than previously reported (Charlebois et al. 1997). The deposition of eggs on the floor of the nest may affect egg survival if increased effort is required by males for nest maintenance.

Five fishes including *Ambloplites rupestris* (Rock Bass), *Micropterus dolomieu* (Smallmouth Bass), *Perca flavescens* (Yellow Perch), *Percina caprodes* (Logperch), and *Neogobius melanostomus* (Round Goby) approached the exposed nest or appeared within the field of view of the camera (20 cm wide) near the nest. A Freshwater Drum (*Aplodinotus grunniens*) also approached the nest, but did not enter the camera's field of view. Each fish that approached the nest could not be identified individually and so the same fish may have left the field of view to reappear later.

Of the five species, most behavioural interactions occurred between the guarding male and other Round Gobies (Table 1). Intruding Round Gobies were typically half the body length or less of the resident male. The sex of Round Goby intruders could not be determined from the video, but all exhibited pale mottled gray and white colours with a distinctive black dot on the dorsal fin. None of the intruders exhibited the charcoal black colouration of breeding males. Of the 65 times that a Round Goby appeared within the field of view, two fish swam by and 63

TABLE 1. Behavioural interactions exhibited by the intruder and the response by the resident male Round Goby on an exposed nest located on a shipwreck, *M. I. Wilcox*, offshore of Colchester, western Lake Erie.

Species	Intruder			Resident Male		
	Number of times fish swam by	Number of approaches	Number of times eggs were eaten	Number of approaches	Number of chases	Number of hits
Rock Bass	1	7	0	6	4	1
Smallmouth Bass	3	7	0	1	0	0
Yellow Perch	1	0	0	0	0	0
Logperch	2	1	0	0	0	0
Round Goby	2	63	4	34	18	4

approaches were noted. In response, the guarding male approached (34 times) or chased (18 times) Round Goby intruders. These approach and chase behaviours were independent events. Four of the 63 approaches by Round Goby intruders resulted in fish eating eggs from the periphery of the nest. In three of the four cases in which eggs were eaten, the resident goby was distracted by the presence of fish other than the successful egg eater (once, by the presence of a Logperch and another Round Goby intruder; a second time by the presence of a Rock Bass; and a third time by the presence of another Round Goby intruder). In all four cases, the resident goby was facing away from the intruder when eggs were eaten. There was no evidence of co-operation or coordinated activities among intruders. In all cases, the guarding male chased the intruder from the nest. Four hits were recorded by the resident male against Round Goby intruders. During our 12 minutes of observation, the guarding male did not feed on eggs within the nest.

Our observations of fish interactions over exposed nests on another shipwreck, the *Conemaugh*, revealed extended fighting bouts between two guarding Round Gobies. In this case, two nests were adjacent and the interactions occurred over the eggs of one nest. Numerous bites and butts were exchanged between the males. Also, the fish would lock jaws and tug away in opposite directions. Neither male was observed feeding on exposed eggs.

In gobiids, females typically mate with males that already have eggs in their nests (Forsgren et al. 1996; Kraak and Weissing 1996). Since guarding males of many species of gobies are known to eat eggs or offspring (Kraak and Weissing 1996), this strategy may dilute the risk of the breeding male eating newly laid eggs. In this study, the strategy would also dilute the risk of predators eating eggs deposited by a single female. Kovtun (1980) reported high egg mortality in larger nests than smaller ones because larger proportions of eggs are exposed and susceptible to predators when nests are large. However, since eggs of most gobiids are covered completely and nests have one small opening, one would not expect differences in egg mortality by intruders.

Response by the resident goby to the presence of Rock Bass (one swam by and seven approached) resulted in six approaches, four chases and one hit (Table 1, Figure 1). All Rock Bass approaches were followed immediately by a chase. The estimated total length (TL) of Rock Bass ranged from 10.5 to 18 cm.

All Smallmouth Bass that approached the nest were juveniles, characterized by distinctive caudal fins "unmistakably marked orange at base followed by a black band" (Scott and Crossman 1973). The largest Smallmouth Bass observed was about 12 cm TL. The Round Goby approached Smallmouth Bass intruders (three swam by and seven approached), only once. The resident male typically hovered over the nest when either one or two Smallmouth Bass approached.

The resident Round Goby male did not respond to either the presence or approach of Logperch (two swam by, one approached) or Yellow Perch (one swam by). However, too few events were observed to suggest that the absence of a response by the resident male was typical.

We observed nest maintenance behaviours by the resident male. Once, the Round Goby picked up a large piece of debris from the edge of the nest and spit it into the water column. A Yellow Perch appeared, swam by, and captured the discarded debris. This was the only incident of a Yellow Perch appearing in the field of view of the camera. Thus, potential predators that are attracted to exposed nests may obtain energy benefits without interacting directly with prey.

The resident male also exhibited fanning behaviour (a mechanism to disperse debris and increase aeration) over the eggs on the nest. The male fanned the nest three times for 2 sec each time. The three fanning episodes occurred during the last 3 min of the observation period.

Several predators of Round Gobies have been reported in the literature. On the basis of stomach analysis of fish caught in the St. Clair River, Walleye (*Stizostedion vitreum*), Smallmouth Bass, Rock Bass, Tubenose Gobies, Stonecats (*Noturus flavus*) and Yellow Perch all ate Round Gobies (Jude et al. 1995). Anglers use Round Gobies for bait to catch Smallmouth Bass. The presence of Round Gobies in

the Flint and Shiawassee rivers in central Michigan are likely the result of bait bucket transfers (D. Jude, CGLAS, University of Michigan, Ann Arbor, personal communication). To limit the distribution of the non-indigenous Round Goby, anglers should be encouraged to empty their bait bucket on land before leaving a waterbody. In Ontario, it is illegal to release baitfish from one waterbody to another (Ontario Ministry of Natural Resources Fact Sheet, undated). Similar regulations exist in the United States.

All types of rocky habitats may be used by Round Gobies, but some locations (i.e., shipwrecks) may be particularly attractive to Round Gobies if predation risk (to eggs, juveniles and adults) is reduced. We suggest that predation rates may be reduced on shipwrecks because of the abundance of cover and crevices available in such a complex structure. In this study, the most successful evidence of predation was by small Round Gobies feeding on eggs at the periphery of the nest. No other predator was successful in preying on eggs in the nest.

Izergyn and Dushkina (1994) reported that Round Gobies spawned on artificial reefs ("polychlorvinyl pipes and polystyrol 'little houses' kapron nets") positioned at depths of 5–7 m in the Sea of Azov. Recruitment of Round Goby stocks increased tenfold during the time (1984–1990) in which the artificial reefs were examined (Izergyn and Dushkina 1994). Although artificial reefs attract several species of fish including piscivores (Brock 1994), these fishes also occupy rocky substrates nearshore. Although it may be unusual for nests to be exposed in nature, it is likely that energetic costs exhibited by males in nest defense are high. Energy costs of nest defense and lack of feeding by guarding males have led to the assumption that males die after spawning (Charlebois et al. 1997). Thus, predation risk may differ between breeding and non-breeding males. If so, dispersal of male Round Gobies may depend on their mating status. We anticipate that the recruitment of Round Gobies will increase substantially in Lake Erie owing to the presence of artificial reefs (shipwrecks) and the ability of guarding males to defend nests effectively.

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The Influence of Close-Range Radio-Tracking on the Behavior of Free-Ranging Striped Skunks, *Mephitis mephitis*

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We assessed the influence of close-range radio-tracking on the behavior of Striped Skunks (*Mephitis mephitis*) in southcentral Saskatchewan. Thirty-five skunks were radio-tracked for 1873 h from April through August, 1993-1994. Most locations (87%) were performed at a distance > 10 m from radio-tracked skunks, whereas 46% were at distances > 20 m. Distance travelled between consecutive 15-min locations was not influenced by human disturbance ($P = 0.67$), or by distance from human observer ($P = 0.09$). Skunks did not seek taller or shorter cover following disturbance ($P = 0.21$) or among observation types (visual, auditory, or triangulation; $P = 0.57$). However, disturbed skunks remained in the same habitat more than undisturbed skunks ($P = 0.03$). We recommend that locations immediately following observer-induced disturbances be excluded in the analysis of space-use patterns of this species. We nonetheless consider close-range radio-tracking a better technique than remote triangulation, especially for disturbance-tolerant species in fine-grained environments.

Key Words: Striped Skunk, *Mephitis mephitis*, behavior, habitat selection, movements, telemetry, triangulation, Saskatchewan.

Conventional triangulation methods using radio-telemetry carry an error related to the imprecision of the triangulation system (Nams 1989; Schmutz and White 1990; Zimmerman and Powell 1995). Although this error can be evaluated (Samuel and Kenow 1992), it can limit inferences about habitat selection (White and Garrott 1986). In fine-grained environments, locational error may also preclude precise assessment of habitat type (Nams 1989), and this error may not be acceptable if the animal makes short movements in relation to the size of the error polygon (White and Garrott 1986; Schmutz and White 1990). Although precise telemetry systems are available (e.g., null-peak systems), fixes must be obtained in close proximity to the study animal to limit measurement error (White 1985), and loss of data may occur when animals move out-of-range of fixed telemetry systems. This has led to the development of ways to mitigate errors associated with radio-locations (Anderson-Sprecher 1994).

Direct observation is the most accurate way of locating an animal, and is limited only by the ability of the observer to locate the animal's position on a map (White and Garrott 1990: 42). However, data collected through observation is useful only if the behavior of the animal is not affected by the presence of the observer (Martin and Bateson 1989: 17). Following a moving animal on foot, aided by the signal of a radio-collar, has been used to obtain precise locations for a wide variety of medium-sized mammals (*Erinaceus europaeus*: Doncaster 1993; *Herpestes ichneumon*: Palomares and Delibes 1993; *Mephitis mephitis*: Crabtree and Broome 1985; *Mustela putorius*: Lodé 1994; *Paradoxurus her-*

maphroditus: Joshi et al. 1995; *Potos flavus*: Julien-Laferrrière 1993; *Vulpes cana*: Geffen and Macdonald 1992).

Most studies involving direct observations do not address possible biases created by the presence of an observer, although in a few instances, semi-tame (Nams 1991) or human habituated animals (Henry 1986; Watanuki and Nakayama 1993) were used, and ways to minimize disturbance suggested (Geffen and Macdonald 1992). However, quantitative testing of the effects of human disturbance on movements is still lacking for most species. In this paper, we assess the impact of close-range radio-tracking on three components of the space-use patterns of Striped Skunks: movements, cover use, and habitat use.

Study Area and Methods

This study was conducted in the parkland region of southcentral Saskatchewan (52°45' N, 107°08' W). Grain (i.e., wheat, barley, oats) and oil crops (mostly canola and flax) occupy 60% of the landscape, and numerous wetlands and stands of Trembling Aspen (*Populus tremuloides*) occupy the remainder of the study area. Topography is gently rolling, and the land is divided by an extensive network of roads. General characteristics of the Prairie Pothole Region are detailed elsewhere (Greenwood et al. 1995).

From April to August, 1993-1994, Striped Skunks were captured and anesthetized using halothane and Telazol® (Larivière and Messier 1996a,b). All individuals were equipped with a 5-sec delay motion sensitive radio-collar (150-152 Mhz, Telonics Inc., Mesa, Arizona, USA) as part of a study on the eco-

gy of Striped Skunks during the waterfowl nesting season (Larivière and Messier 1997a, 1998). Skunks were released at the site of capture.

Striped Skunks were radio-tracked in the 12-hour block from 1800 to 0600. Animals were located by a single observer, on foot, every 15 min, preferably by sight, but also by sound, and short-range (< 50 m) triangulation. Throughout tracking, observers remained downwind, silent, and as far as possible from the animal while still being able to locate the skunk accurately. Furthermore, observers only moved when radio-collared animals moved, as indicated by the motion sensor. No headphones were used with the telemetry receiving unit to facilitate awareness of auditory warnings by skunks (Larivière and Messier 1996c) and to facilitate locating skunks by sound. To minimize auditory disturbance, receiver gain was kept to a minimum, and receiver was used only when the skunk was out of sight. Light-amplifying, night-vision goggles (AN-PVS 5, Bill's Electronics Ltd., Mildmay, Ontario) facilitated visual observations at night.

At each location, distance between skunk and observer was paced (1 step = 1 m), following departure of the skunk, and classified in one of four categories: 0-5, 6-10, 11-15, and 15-50 m. Observations > 50 m were excluded from analysis as they were often associated with rapid and extensive movements by the skunk.

At each location, mean height of vegetation was classified as 0-0.5, 0.5-1, and > 1 m. Habitat type was recorded and then classified in six cover categories defined *a priori* according to overall thickness and height of vegetation: (1) fallow fields, (2) pastures, (3) farmsteads, fencelines and rights-of-way, (4) cropland, (5) hayland, and (6) woodland and wetlands.

Universal Transverse Mercator coordinates were obtained from the exact location of the skunk following its departure from the area using a portable Global Positioning System (Ensign GPS, Trimble Navigation, Cansel Survey Equipment, Burnaby, British Columbia). Distances between consecutive 15-min locations were determined using UTM coordinates incorporated in the software package Ranges IV (Kenward 1990).

Striped Skunks exhibit aposematic (i.e., warning) behavior when disturbed, and defensive postures are obvious (Larivière and Messier 1996c). Time and distance between skunk and observer during "observer-induced disturbances" (subsequently referred to as a disturbance) were recorded throughout tracking. A disturbance was defined as an encounter between a human observer and a skunk which triggered defensive behaviors by the skunk (Larivière and Messier 1996c). Each location was classified as: (1) no obvious disturbance occurred (i.e., no defensive behavior exhibited by skunk)

within last 15 min, or (2) at least one obvious disturbance (i.e., defensive behavior exhibited) occurred within the last 15 min.

We investigated the effect of disturbance on skunk movements using a Wilcoxon signed-rank test. Then, we investigated how distance from human observer influences skunk movements using a Friedman two-way analysis of variance on ranks. Chi-square tests of homogeneity were used to assess the influence of vegetation height and cover on the probability of disturbance, type of observation (visual, auditory, triangulation), and probability that the skunk moved to a different habitat following disturbance. Two-tailed probability levels were used and *P* values < 0.05 were considered significant.

Results

Thirty-five Striped Skunks (7 males, 28 females) were radio-tracked during 1873 h (858 and 1015 h of tracking for 1993 and 1994, respectively), yielding 3821 locations of active skunks. During tracking, human disturbances preceded 4.3% of all locations.

Visual observations of skunks were predominant in early spring, and decreased in favor of auditory and short-range triangulation locations with vegetative growth in summer (Figure 1). Most locations (87%, *n* = 3647) were performed at distances > 10 m from radio-tracked skunks, whereas 68% and 46% of the locations were at distances > 15 and > 20 m from skunks, respectively (Figure 2).

We did not detect an effect of human disturbance on skunk movement between consecutive 15-min locations (Wilcoxon signed-rank test, $T^+ = 136$, $Z = -0.4$, $P = 0.70$). Similarly, distance moved by skunks between consecutive 15-min locations was not strongly influenced by distance from observer (Friedman two-way analysis of variance, $F_r = 6.6$, $n = 19$, $k = 4$, $P = 0.09$), although skunks moved

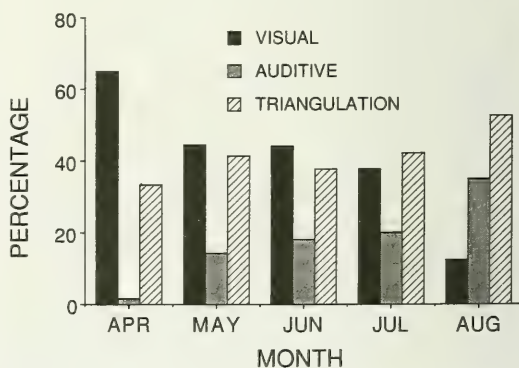


FIGURE 1. Type of observations used for locating radio-collared Striped Skunks at night during April through August, 1993-1994, in southcentral Saskatchewan (*n* = 3647 locations).

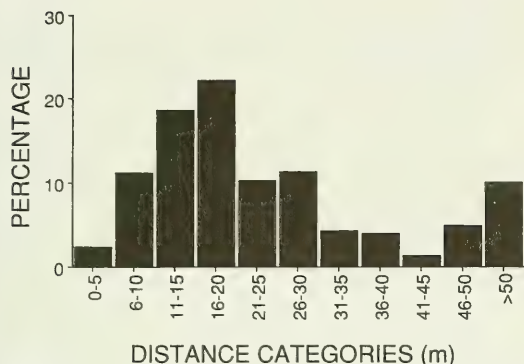


FIGURE 2. Distances between observers and Striped Skunks during each location during April through August, 1993-1994, in southcentral Saskatchewan (n = 3647 locations).

slightly longer distances when observations were taken <5 m away (Figure 3).

Observation type (e.g., visual, auditory, triangulation) was correlated with cover height ($\chi^2 = 466.8$, $df = 4$, $P < 0.01$). Disturbance was more likely to occur in shorter vegetation ($\chi^2 = 22.8$, $df = 2$, $P < 0.01$), and following visual observations ($\chi^2 = 19.1$, $df = 2$, $P < 0.01$). We analyzed changes in cover height only for skunks located in vegetation height class two to prevent a systematic bias associated with cover height category 1 (0-0.5 m) and 3 (> 1 m) (e.g., skunk in height class one can only change to taller cover and vice versa for height class three). Skunks changed vegetation height classes independently of observation type ($\chi^2 = 1.13$, $df = 2$, $P = 0.57$), or disturbance (Fisher's exact test, $P = 0.21$). Similarly, skunks did not change habitats more often following human disturbance ($\chi^2 = 2.07$, $df = 1$, $P = 0.15$), or whether the previous observation was visual, auditory, or triangulation ($\chi^2 = 4.03$,

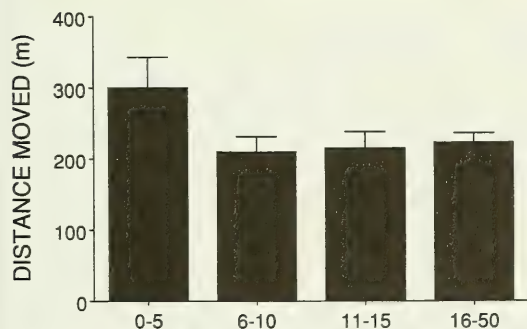


FIGURE 3. Distance moved between consecutive 15-min locations in relation to distance between observer and Striped Skunks (n = 19) during April through August, 1993-1994, in southcentral Saskatchewan. None of the means differ statistically.

$df = 2$, $P = 0.13$). When habitats were classified by their density and cover thickness, skunks did not show any tendencies to go for denser or sparser habitat types depending on the observation type ($\chi^2 = 3.73$, $df = 2$, $P = 0.16$). However, disturbed skunks remained in the same cover type more than undisturbed skunks (Fisher's exact test, $P = 0.03$).

Discussion

Although our design lacked a true control level (i.e., observer present versus observer not present), the lack of effect of disturbance and observer distance on movement and habitat use suggests that the presence of an observer had minimal influence on the behavior and space-use patterns of free-ranging Striped Skunks. Striped Skunks rely on aposematic behavior to deter predators (Walton and Larivière 1994; Larivière and Messier 1996c), and aposematic behavior is effective and displayed only when predators are in close proximity (Walton and Larivière 1994; Larivière and Messier 1996c; see also Cott 1940; Cloudsley-Thompson 1980). This may explain why skunks are so tolerant of human observers. Furthermore, skunks commonly display short (< 2 min) defensive behaviors during nightly foraging expeditions, often to non-predatory species (Larivière and Messier 1996c). Finally, Striped Skunks are nearsighted, and rely strongly on olfactory and auditory cues to locate prey and predators (Langley 1979; Larivière and Messier 1996c; Nams 1991, 1997). By remaining silent and downwind, observers could successfully observe foraging animals and rarely (< 5% of locations) induced defensive reactions. Furthermore, direct observation enabled radio-trackers to observe some interactions between skunks and other predatory or non-predatory animals (Walton and Larivière 1994; Larivière and Messier 1996c, 1997b).

Use of cover as an escape strategy by Striped Skunks is unusual (Larivière and Messier 1996c). Our data indicated that skunks do not change cover type following disturbance, and that disturbed skunks tended to remain in the same cover type. For this reason, and to prevent any possible bias arising from unnoticeable disturbance events or observer-related stress, we recommend that locations immediately following a disturbance event should be excluded from behavioral analyses. Nonetheless, we believe that close-range radio-tracking is a better technique than conventional triangulation methods, especially when studying relatively slow moving mammals that use close-range defense mechanisms (i.e. Striped Skunks; Porcupines, *Erethizon dorsatum*) and fine-grained habitats such as fragmented farmland/prairie landscapes.

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Importance of Fire in Alvar Ecosystems — Evidence from the Burnt Lands, Eastern Ontario

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Vascular plants recorded within 50 one metre square quadrats in 1997 in an area cut and burned 37 years earlier revealed an unusually high species diversity with 87 native vascular plant species, which is roughly twice as high as that recorded in various open areas of alvars that have not recently been burned. Site conditions appear to have favoured native species over weedy aliens, the latter accounting for 21% of species in quadrats, but having low cover values. The sampled area was dominated by graminoid plants and shrubs, and was transitional between alvar shrubland and alvar grassland. The saplings present were mostly Trembling Aspen, *Populus tremuloides*, and White Spruce, *Picea glauca*. The cut and burned area included 16 rare and/or restricted species. Some of the prominent vascular plants serve as larval foodplants for restricted butterflies, and the high species diversity and more mesic conditions in successional openings ensure adequate adult nectar sources. The burned site also provided habitat for rare birds. Considering these observations and because the vast majority of alvars have burned within the past few centuries, it is concluded that successional alvar burns deserve recognition as an important part of the alvar ecosystem and that burning of an alvar habitat is an appropriate management consideration. Management plans should account for certain fire-susceptible features such as ancient trees and arthropod populations.

Key Words: alvar, fire, flora, wildlife, species diversity, rare species, succession, management, biomass removal, prescribed burn, Great Lakes, Ontario, Canada.

Alvars are “naturally open areas of thin soil over essentially flat limestone or marble rock with trees absent or at least not forming a continuous canopy” (Catling and Brownell 1995). Fires were characteristic of limestone plateaus in early settlement and presettlement times. That the alvars and surrounding woodlands burned where biomass was sufficient is evidenced by charcoal, charred wood and stumps, and records of early settlers. The effect of fire is to increase the size of an alvar (i.e., the natural opening) which then closes in again as a result of succession to the opening that can be maintained by other factors.

Although Catling and Brownell (1995) did not highlight fire as a major factor in the maintenance of alvar, Catling et al. (1975) noted that “the shallow droughty soils and coniferous forests characteristic of many limestone plateaus make these areas highly susceptible to burning, and fires may therefore play a key role in the maintenance of alvar vegetation.” Schaefer (1996a*) concluded to the contrary that “large scale biomass-removing disturbances are not a necessary condition for the maintenance of alvar habitat”, and “prescribed burns should not be considered a management tool in Bruce Peninsula alvars, and possibly elsewhere”. These statements were made on the basis of work on the Bruce Peninsula where fires on inland alvars are particularly well documented (Suffling et al. 1995*). Later

Schaefer (1996b*) concluded on the basis of a comparison of 1930 and 1978 air photos as well as early survey records, that “prescribed burns may be appropriate at alvar sites that have strong evidence of past fires”. More recently Schaefer and Larson (1997) further implied a controversy over the importance of fire noting the lack of burning in some sites based on presence of ancient trees and the absence of different vegetation between burned and unburned sites. They also noted the hypothesis that “fire at burned alvars is only incidental, and maintenance by drought actually prevails”. We (Catling and Brownell *in press*) drew attention to the potential role of fire in alvar shrublands and alvar savannas, but noted a lack of adequate assessment, and recommended more research on ecological processes including fire.

In 1960 the Department of National Defense (DND) cut and burned wooded areas within an alvar mosaic in the Burnt Lands, an extensive limestone plateau in eastern Ontario 38.5 km WSW of Ottawa (north side of regional road 44, 5 km NE of Almonte, Figure 1) thus providing an opportunity for assessment of vascular flora associated with a recent fire. The cutting and burning was done to prevent disruption of communication in an antenna yard site. Although it may have been subject to grazing prior to 1960, the area had not been impacted by humans or livestock for 37 years. It is possible using pre-1960 aerial photographs to identify accurately the areas where woody vegetation had been cut and burned. It is also possible to identify the

*See Documents Cited section

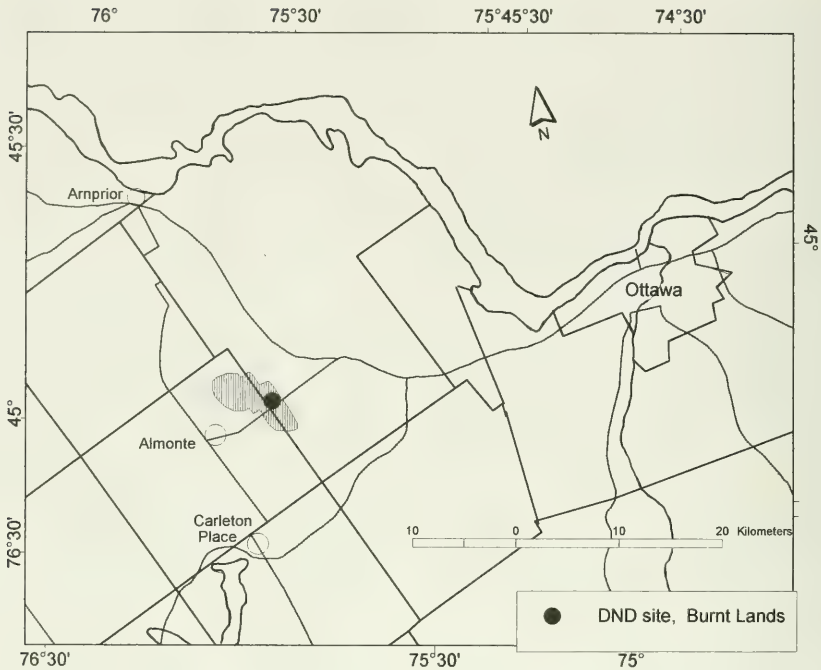


FIGURE 1. Ottawa region of eastern Ontario showing the location of the Burnt Lands (shaded) and the study area (dot).

previously wooded area by the abundant stumps. The Burnt Lands has been identified as a "fire-dependent environment of great provincial significance" that "will require continued renewal by periodic burning if its important natural values are to be preserved" (Brunton 1986*). The most recent fire probably occurred in August 1870 and was the one that resulted in the area being called "The Burnt Lands" (Walker and Walker 1968), and it was also one of several major fires that burned hundreds of square km through the townships around Ottawa at the same time. Recent abandonment of site by the Department of National Defence and the uncertainty of its future has refocused attention on the biological significance of the Burnt Lands, and the processes that maintained this provincially significant ecosystem, thus leading to the following discussion. The objective is to provide a better understanding of the potential significance of biomass removal, including fire, in terms of species diversity and occurrence of rare and restricted species, as well as an indication of floristic composition and successional trends. Examination of a "burn" also gives an indication of the importance of some kind of management of woody vegetation and is relevant to strategic direction 2.4c of Canada's response to the International Convention on Biological Diversity (Biodiversity Convention Office 1995).

Methods

Two areas, 38.5 km WSW of Ottawa at 45°15'36"N, 76°08'38"W, and 45°15'54"N, 76°09'15"W, in lots 16 & 17, concession 12, West Carleton Township, Regional Municipality of Ottawa-Carleton, were identified as forested in 1953 air photos. These areas were cleared and burned and scarified in 1960 when the area was used as an antenna yard site, and there was no subsequent vegetation control (Lezlie Locke, DND property officer, personal communication). The forest composition was determined based on examination of the 1953 air photos and comparison with surrounding woodland that had developed naturally without cutting for at least 75 years.

Fifty one-metre square quadrats were set out at 5 – 10 m intervals along transects run through the previously wooded area, which was clearly evident as a result of the presence of stumps, most of which were charred, throughout the area. Some species could only be tentatively identified, but the tentative identifications are considered reliable based on familiarity with the flora at this site. In a case where most of the occurrences of a species were definite (e.g., *Solidago nemoralis*), a few indefinite records (very small rosettes probably referable to *Solidago nemoralis*) were included with the probable identification (*S. nemoralis*; i.e., without an additional "cf." category) so as to keep the list to a minimum

for consideration of species diversity. In fact there were few such cases.

Results

Prior forest composition

Based on examination of the air photos and forest occupying adjacent areas at the present time, the previously wooded areas had been covered by a woodland without glades that included White Spruce (*Picea glauca*), Trembling Aspen (*Populus tremuloides*), White Pine (*Pinus strobus*), Eastern White Cedar (*Thuja occidentalis*), and Balsam Fir (*Abies balsamea*), with smaller amounts of Bur Oak (*Quercus macrocarpa*), Red Oak (*Quercus borealis*), Red Pine (*Pinus resinosa*) and possibly some Tamarack (*Larix laricina*) in the lower areas. The terrain was hummocky with differences of up to 0.3 m in elevation occurring over distances of one metre. The soil is mostly shallow varying from limestone gravel and sand or mostly organic material, 0.25 m deep to sand up to 2 m deep, in all cases overlying more or less flat limestone rock.

Successional trends

Adjacent wooded areas have forests that appear younger than 75 years, whereas the most recent major fires occurred in August 1870 (Walker and Walker 1968); i.e., 127 years ago. A prolonged early succession could explain why the trees are much younger than the period since the last fire. The woody species that were recorded in the transects (Table 1) included Wild Rose (*Rosa acicularis* 52%), Bearberry (*Arctostaphylos uva-ursi* 34%), Snowberry (*Symphoricarpos albus* 26%), Choke Cherry (*Prunus virginiana* 24%), Poison Ivy (*Rhus radicans* ssp. *rydbergii* (20%), Willow (*Salix* cf. *discolor* 12%), Low Sweet Blueberry (*Vaccinium angustifolium* 12%), and Juneberry (*Amelanchier alnifolia* var. *compacta* 6%), but trees including Trembling Aspen (6%) and White Spruce (4%) had much lower frequencies. As suggested by the quadrat data, shrubs appear to colonize before trees, and White Spruce and Poplar are evidently the most frequent early colonizers. Some Trembling Aspen may have regrown from roots that survived the cutting and burning. Eastern White Cedar, White Pine, Red Pine, Bur Oak and Red Oak were less frequent. All saplings were 1–12 years old.

The term "alvar successional burn" separates those portions of an alvar dependent mostly on fire (or large scale biomass removal) from those maintained largely by drought and extremes of soil moisture. "Alvar successional burns" evidently include successional phases of previously defined alvar habitats (e.g., Catling and Brownell *in press*). The sampled area in the Burnt Lands was dominated by graminoid plants and shrubs, and was transitional between alvar grassland and alvar shrubland. The most conspicuous alvar communities in relation to

fire are probably the "alvar shrublands" and "alvar savannas" which may be a mid-successional phase of either very long or short duration. That some of these kind of communities are not entirely drought maintained is suggested by presence of charcoal from past fire, presence of old tree stumps and presence of younger trees. A long successional stage would probably involve filling in of the canopy very slightly over periods of 50–100 years, whereas a short duration would involve complete return to forest within the same period. Alvar grassland dominated by Poverty Grass (*Danthonia spicata*) is probably a characteristic early successional stage, although not all grasslands dominated by Poverty Grass are either successional or fire-dependent. Later successional stages could involve "alvar savanna" and "alvar woodlands" (see Catling and Brownell *in press*) and eventually conifer or mixed forests.

Modal species

The native species with the highest frequencies may be considered characteristic. Although some of these are major components of habitats other than burns, it appears that some such as Lindley's Aster (*Aster ciliolatus*) reach their maximum frequency and cover in the alvar successional burns. Plant species that were/are probably more frequent on successional alvar burns than in any other natural habitat in the region (Ottawa-Carleton) are shown in boldface in Table 1. There are 24 of these and several rare and restricted species are included.

Number of species

In the 50-one metre square quadrats, 87 native and 22 introduced vascular plants were recorded (Table 1). The average number of native vascular plants/quadrat was 14.8, with a range of 7–30, and a standard deviation of 5.07. This is a relatively high species richness. Quadrat surveys of double the size; i.e., 100 square metres; in other parts of the Burnt Lands, in other habitats including a number of different kinds of alvar grassland, as well as pavements and woodland, had 27–44 native species (D. Cuddy, personal communication). Quadrat surveys of 100 square metres at each of six sites on Manitoulin Island had 27–38 native species (J. Jones, personal communication). The relatively high species numbers of successional burned sites can be explained in a number of ways. Firstly some forest and semi-shade species persist following removal of woody cover (e.g., *Carex eburnea*, *Carex richardsonii*, *Carex pensylvanica*), while species of open alvar pavements and alvar grassland invade to some extent (e.g., *Solidago ptarmicoides*). Another group appears related particularly to the succession (e.g., *Aster ciliolatus* and *Cirsium discolor*). Consequently several different habitats are represented in the successional site. In addition the depth of substrate over rock is greater than in openings maintained by

TABLE 1. Frequencies of vascular plants recorded in 50 one-metre square quadrats on previously wooded portions of the Burnt Lands Alvar. + = introduced. (+) = possibly introduced. * = regionally rare and native. Plant species that were/are probably more frequent on successional alvar burns than in any other natural habitat (i.e. modal species) in the region (Ottawa-Carleton) are shown in boldface. The names are arranged alphabetically (by genus and species) within percentage frequency classes. Letters indicate various classes of rarity: E = rare in eastern Ontario (Cuddy 1991*). P = provincially rare. R = rare in Regional Municipality of Ottawa-Carleton (Brunton 1997*). S = sparse in Regional Municipality of Ottawa-Carleton (Brunton 1997*).

% Frequency	Status	Scientific Name
92		Danthonia spicata (L.) R.&S.
72		Smilacina stellata (L.) Desf.
70		Fragaria virginiana Dcne.
64	ER	Carex richardsonii R.Br.
58	+	Hieracium piloselloides Vill. (<i>H. florentinum</i> All.)
56		Aster ciliolatus Lindl.
52		Rosa acicularis Lindl.
50		Bromus kalmii A. Gray
50		Campanula rotundifolia L.
50		Muhlenbergia glomerata (Willd.) Trin.
50		Poa pratensis L.
42	+	Chrysanthemum leucanthemum L.
40		Achillea millefolium L.
36		Carex lanuginosa
34		Arctostaphylos uva-ursi (L.) Spreng.
34		Carex pensylvanica Lam.
34		Comandra umbellata (L.) Nutt.
28		Peridium aquilinum (L.) Kuhn var. latiusculum (Desv.) Underw.
28		Solidago nemoralis Ait.
28	+	Trifolium aureum Poll. (<i>T. agrarium</i> L.)
26		Symphoricarpos albus (L.) Blake var. albus
26	+	Vicia cracca L.
24	+	Hypericum perforatum L.
24		Prunella vulgaris L.
24		Prunus virginiana L.
24		Waldsteinia fragarioides (Michx.) Tratt.
22	(+)	Poa compressa L.
20		Carex eburnea Boott
20	ER	Cirsium discolor (Muhl.) Spreng.
20		Rhus radicans L. ssp. rydbergii (Sm. ex Rydb.) McNeill
20	E	Solidago bicolor L.
18	+	Agrostis gigantea Roth
18		Equisetum arvense L.
18	+	Taraxacum cf. officinale Weber
16	R	Carex umbellata Willd.
14		Agropyron trachycaulum (Link) Malte ex H.F. Lewis
14		Aster lanceolatus Willd. (<i>A. simplex</i> Willd.)
14		Carex castanea Wahl.
14		Juncus dudleyi Wieg.
14		Satureja vulgaris (L.) Fritsch var. neogaea Fern.
14		Senecio pauperculus Michx.
12		Antennaria neglecta Greene (including <i>A. neodioica</i> and <i>A. canadensis</i>)

TABLE 1. Continued.

% Frequency	Status	Scientific Name
12		Apocynum androsaemifolium L.
12		Gaultheria procumbens L.
12	+	Linaria vulgaris Mill.
12		Salix cf. discolor Muhl.
12		Sisyrinchium montanum Greene
12		Vaccinium angustifolium Ait.
10		Lactuca cf. biennis (Moench) Fern.
10		Panicum lanuginosum Ell. var. implicatum (Scribn.) Fern. (<i>P. implicatum</i> Scribn.)
10		Polygala senega L.
10		Solidago canadensis L.
10	+	Trifolium pratense L.
8		Anemone cylindrica Gray
8		Gentiana crinita Froel.
8	+	Lythrum salicaria L.
8	+	Medicago lupulina L.
8	R	Panicum xanthophysum A. Gray (<i>Dichanthelium</i> x. (<i>A. Gray</i>) Freckm.)
8	ER	Viola adunca Sm.
6		Agrostis scabra Willd.
6	R	Amelanchier alnifolia Nutt. var. compacta (Nielsen) McKay
6		Aster ptarmicoides (Nees) T.& G.
6		Carex tenera Dewey
6		Populus tremuloides Michx.
6	+	Ribes cynosbati L.
6	+	Rumex acetosella L.
6		Solidago juncea Ait.
6	+	Tragopogon cf. pratensis L.
4	R	Carex houghtoniana Dewey
4		Cypripedium calceolus L. var. pubescens (Willd.) Corr.
4	+	Echium vulgare L.
4		Juniperus communis L. var. depressa Pursh
4	+	Melilotus alba Medic.
4	+	Phleum pratense L.
4		Picea glauca (Moench) Voss
4		Polygala paucifolia Willd.
4		Rubus strigosus Michx.
4		Sporobolus vaginiflorus (Torr.) Wood
4		Viola cf. conspersa Reich.
2	E	Amelanchier spicata (Lam.) K. Koch var. stolonifera (Wieg.) Cinq-Mars
2		Aquilegia canadensis L.
2		Asclepias syriaca L.
2		Aster umbellatus Mill.
2	EPR	Astragalus neglectus L.
2		Botrychium multifidum (Gmel.) Rupr.
2		Carex granularis Muhl. ex Willd.
2	+	Cerastium fontanum Baumg. (<i>C. vulgatum</i> L.)
2	+	Chaenorhinum minus (L.) Lange
2		Diervilla lonicera Mill.
2		Erigeron cf. annuus (L.) Pers. ssp. strigosus (Muhl. ex Willd.) Wagenitz
2		Lilium philadelphicum L.
2	E	Lonicera hirsuta Eat.
2		Lonicera dioica L.
2	E	Melampyrum lineare Desr.

TABLE 1. *Concluded.*

% Frequency Status		Scientific Name
2		<i>Oenothera</i> cf. <i>parviflora</i> L.
2		<i>Oryzopsis asperifolia</i> Michx.
2		<i>Panicum philadelphicum</i> Trin.
2		<i>Panicum linearifolium</i> Britt. (<i>Dichanthelium linearifolium</i> (Scribn.) Gould)
2		<i>Panicum flexile</i> (Gatt.) Scribn.
2	E	<i>Petasites palmatus</i> (Ait.) Gray
2	+	<i>Potentilla recta</i> L.
2	E	<i>Pyrola</i> cf. <i>americana</i> Sweet (<i>P. rotundifolia</i> L.)
2		<i>Quercus macrocarpa</i> Michx.
2		<i>Salix petiolaris</i> Sm.
2		<i>Shepherdia canadensis</i> (L.) Nutt.
2		<i>Vaccinium myrtilloides</i> Michx.
2	E	<i>Viola nephrophylla</i> Greene

drought and moisture extremes alone leading to more mesic conditions. The high species number and more mesic conditions in successional openings ensure adequate adult nectar sources for restricted butterflies, and undoubtedly enhance faunal species diversity in other ways. In addition the area surveyed has sand deposits of various depths which are sometimes deep enough to limit the chemical impact, although not the drought impact, of the underlying limestone. This leads to presence of species in some areas that are characteristic of acid soils such as blueberries (*Vaccinium* spp.). However sand deposits are not unusual on alvars and account for floristic diversity in other areas such as the Bruce Peninsula, Manitoulin Island and on the Carden Plain.

Rare and restricted species

The list (Table 1) includes 16 species with some category of rarity. Some of these evidently include species characteristic of successional alvar burns such as the provincially rare Cooper's Milk-vetch (*Astragalus neglectus*) and the regionally rare Richardson's Sedge (*Carex richardsonii*). The rare Two-coloured Thistle (*Cirsium discolor*) may have one of its largest populations in the province on the cut and burned portions of this site where over 2000 plants occur within an area of 15 acres. Other rare vascular plant species are present in the cut and burned area including a clubmoss, *Lycopodium complanatum* var. *complanatum* (regionally) and Ram's Head Lady's-slipper Orchid (*Cypripedium arietinum*, provincially), but were not recorded in quadrats. Several locally restricted species also occurred in the cut and burned area including Kalm's Brome (*Bromus kalmii*), panic grasses (*Panicum flexile*, *Panicum philadelphicum*), Red Pine (*Pinus resinosa*), and Upland White Goldenrod (*Solidago ptarmicoides*). The number of rare species and the high frequencies of some suggest that successional

alvar burns may be significant in protection of rare plant species in addition to their being a critical habitat. Provincially rare species at other sites, possibly associated with successional alvar burns, include Juniper Sedge (*Carex juniperorum*), Hill's Thistle (*Cirsium hillii*) and Dwarf Lake Iris (*Iris lacustris*). Fires have also contributed to succession and opening of the forest where provincially rare species of very shallow soils, such as Lakeside Daisy (*Hymenoxys herbacea*), Limestone Oak Fern (*Gymnocarpium robertianum*) and Purple Cliff-brake (*Pellaea atropurpurea*), occur on the Bruce Peninsula, although drought may also be an important factor in these instances.

The fauna dependent on plants characteristic of alvar successional burns includes such geographically restricted butterflies as the Pearl and Dark Crescents (*Phycioides tharos tharos* and *P. batesii batesii*) which use Lindley's Aster as a larval foodplant (Catling 1997a, b), the Chryxus Arctic (*Oeneis chryxus*) which uses Poverty Grass as a larval foodplant (personal observation), and Frosted Elfin (*Callophrys polios*) which uses Bearberry as a larval foodplant (personal observation). One of the largest populations of Dark Crescent in the Ottawa area is in a similar nearby site along a hydro line 2.5 km southeast of Manion Corners (45°14'30"N, 76°02'50"W) where trees were removed to protect the lines and to maintain access (Figure 2). This open area bounded by secondary mixed woodland on shallow soil over limestone, provides an example of an alvar burn type situation that is not closely associated with a large and long-persisting alvar opening. Successional vegetation on the Burnt Lands and within the burned portion of the DND lands is also habitat for regionally rare birds such as the Clay-colored Sparrow and Rufous-sided Towhee (Brunton 1986*, personal observation).

Introductions

The plant associations were generally dominated by native species. Some introduced species, such as Ox-eye Daisy (*Chrysanthemum leucanthemum*), Hawkweed (*Hieracium piloselloides*), Vetch (*Vicia cracca*), and Common St. John's-wort (*Hypericum perforatum*), had very high frequencies but relatively low cover and were not dominant. Common Buckthorn (*Rhamnus cathartica*), Glossy Buckthorn (*Rhamnus frangula*) and Common Barberry (*Berberis vulgaris*), were sparse in the cut and burned area but, based on their dominance in other habitats, they may be more potentially serious competitors than any of the introduced species recorded in the quadrat survey. The proportion of introduced species (21%) was relatively low considering that weedy species of European origin were frequent in the surrounding landscape and that the site was scarified following cutting and burning, thus allowing greater opportunity for colonization of weedy species than would have otherwise been the case.



FIGURE 2. Opening in conifer forest on shallow soil over limestone created by cutting along a hydro line, 2.5 km south-east of Manion Corners near Ottawa. The vegetation here is similar to successional alvar burn and supports a species rich assemblage of plants and animals including rare species.

However, the site condition itself appears to have favoured native species over weedy aliens.

Discussion

Significance of fire

Openness, or lack of tree cover, a key feature of alvars, may be maintained by any one of a number of factors, or a combination of factors including seasonal and periodic drought, extremes of soil moisture, cold onshore winds, shallow soils, grazing, and fire. The relative importance of these factors in maintenance of alvar vegetation will vary from site to site. Plant communities and habitats maintained by drought, or other factors, may be very similar to those maintained by fire. Drought-maintained pavements and grasslands for example may not be much affected by fires, possibly explaining the observations of Schaefer and Larson (1997), but certain alvar communities such as shrublands, savanna and various transitions may be more or less fire dependent, and the evidence suggests that more or less wooded edges of alvars are profoundly affected by fire leading to significant communities; i.e., successional alvar burns, that deserve recognition. Undoubtedly the fact that biologists have focussed

attention on alvar openings rather than the ecosystem or the surrounding forest may also explain the fact that burned and unburned sites have not been distinguished and fire has not been considered important and potentially beneficial. The lack of recent fires has also made the importance of large scale biomass removal less clear. To a large extent, the only sites where vegetation similar to successional alvar burn exists are those where forest has been cut (Figure 2) and such situations are often automatically and erroneously considered to be biologically degraded, rather than the starting point of a significant succession that has become a rare event.

Successional alvar burns may be more or less open for hundreds of years, may relate to a number of alvar communities such as shrublands, savannas, open woodlands and various transitions, may be species-rich, and may contain rare species. These latter points, however, should not be necessary to attract attention of biologists. Even a relatively species-poor alvar shrubland dominated by impenetrable Spreading Juniper (*Juniperus communis*) that is a consequence of fire, is part of an ecological process and provides a very important food resource for Cedar and Bohemian waxwings. It seems appropri-

ate to acknowledge the significance of fire and consider alvars as dynamic openings that expand and contract over time and are part of an equally significant ecosystem or landscape that includes rather than excludes the surrounding forest. Recognition of succession is appropriate as in the case of other open habitats, such as dune systems and prairies.

Fire management

Fire is used as a management tool in many ecosystems throughout North America (Wright and Bailey 1982). The burning of an alvar habitat, regardless of the presence or absence of evidence of past fire, is an appropriate consideration, because the vast majority of alvars have burned, even though some may be found that have not burned for 500 years based on presence of ancient trees (Schaefer 1996a,b; Schaefer and Larson 1997). We would add some emphasis to the word "consideration" and note that it may be appropriate to spare old growth trees from burning, as would occur under natural conditions due to isolation within limestone pavements, onshore winds, chance, etc. Furthermore, burning is best done in patches simulating the way natural fires frequently operate. In some cases it is appropriate to burn only 20–30% of a community at a time. Unburned patches would protect populations of fire-susceptible arthropods (for a review see Siemann et al. 1996). Where burning is not feasible, tree removal by cutting may result in communities similar to successional alvar burns, but the effect may be temporary and debris (slash) must be removed.

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Predation Risk and Foraging Behaviour: An Experimental Study of Birds at Feeders

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Influence of predation risk on the foraging behaviour of seven species of passerine birds was examined in London, Ontario (43°N, 81°W). Feeders containing black sunflower seeds were set up 1.7m, 2.7m, and 3.7m away from a dense row of cedar trees (*Thuja* sp.). The species and number of individuals at each feeder were recorded during 34 thirty-minute observation periods. Seed consumption during each observation period was also measured. Overall, there was a strong tendency for birds to feed close to cover. Variation in use of escape cover and foraging strategies, however, resulted in interspecific variation in feeding location. House Sparrows (*Passer domesticus*), White-crowned Sparrows (*Zonotrichia leucophrys*), Northern Cardinals (*Cardinalis cardinalis*), and Dark-eyed Juncos (*Junco hyemalis*) used feeders closer to cover more than those farther away. Conversely, House Finches (*Carpodacus mexicanus*) fed more frequently at feeders farther from cover. Black-capped Chickadees (*Poecile atricapillus*) and Red-breasted Nuthatches (*Sitta canadensis*) fed independently of feeder proximity to cover but these two species always carried food items to cover for consumption. When food became depleted in the feeders closest to cover, House Sparrows, House Finches, and Dark-eyed Juncos increased their use of the more distant feeders. Our results suggest that proximity to cover has a significant effect on foraging decisions of some species of birds.

Key Words: Predation risk, foraging behaviour, passerines, distance to cover, bird feeder, London, Ontario.

Presumably, a foraging bird should attempt to maximize rate of energy consumption while minimizing time that it is exposed to predators. However, because food exists in varying abundance and quality, and risk of predation varies in time and space, maximal foraging efficiency is frequently incompatible with predation avoidance (Suhonen 1992). This is especially true in winter when food is scarce.

Many avian predators; [e.g., Sharp-shinned Hawk (*Accipiter striatus*), American Kestrel (*Falco sparverius*), and Merlin (*Falco columbianus*)]; use a "flush and pursue" strategy to catch small birds. Undoubtedly, the probability of such a predator catching a small bird is a function of the bird's distance to escape cover. Consequently, it has been argued that foraging behaviour of birds is influenced by their proximity to dense vegetation that provides protection from predation (Suhonen 1992; Schneider 1984; Grubb and Greenwald 1982).

Research has shown that birds do alter their behaviour in response to perceived predation risk. Cowie and Simons (1990) found that Blue Tits (*Parus caeruleus*) and House Sparrows (*Passer domesticus*) exhibited strong tendencies to feed close to escape cover. Food consumption at feeders adjacent to cover was two times higher than at feeders 7.5 m away. Schneider (1984) discovered that White-throated Sparrows (*Zonotrichia albicollis*)

foraged at a significantly higher frequency at feeders close to cover and birds virtually depleted the food before moving farther from cover to feed.

Predation risk also influences the tendency of birds of several species to carry food to cover for consumption. Maximum feeding efficiency is achieved by remaining in a patch to feed, but by carrying food to cover the bird minimizes predation exposure even though it expends more energy (Valone and Lima 1987). Therefore, as predation risk increases, carrying is more frequently employed as a foraging strategy (Valone and Lima 1987).

In this study, we investigated whether perceived predation risk influenced foraging behaviour of seven species of passerine birds: House Sparrow (*Passer domesticus*), House Finch (*Carpodacus mexicanus*), White-crowned Sparrow (*Zonotrichia leucophrys*), Red-breasted Nuthatch (*Sitta canadensis*), Black-capped Chickadee (*Poecile atricapillus*), Northern Cardinal (*Cardinalis cardinalis*), and Dark-eyed Junco (*Junco hyemalis*). The experiment forced the birds to choose among three feeding sites that had equal amounts of food, but were at different distances from cover. Our prediction was that birds would forage at a higher frequency at feeders closest to cover. We also predicted that as food in feeders close to cover became less abundant during an observation period, the birds would move to the next closest feeder.

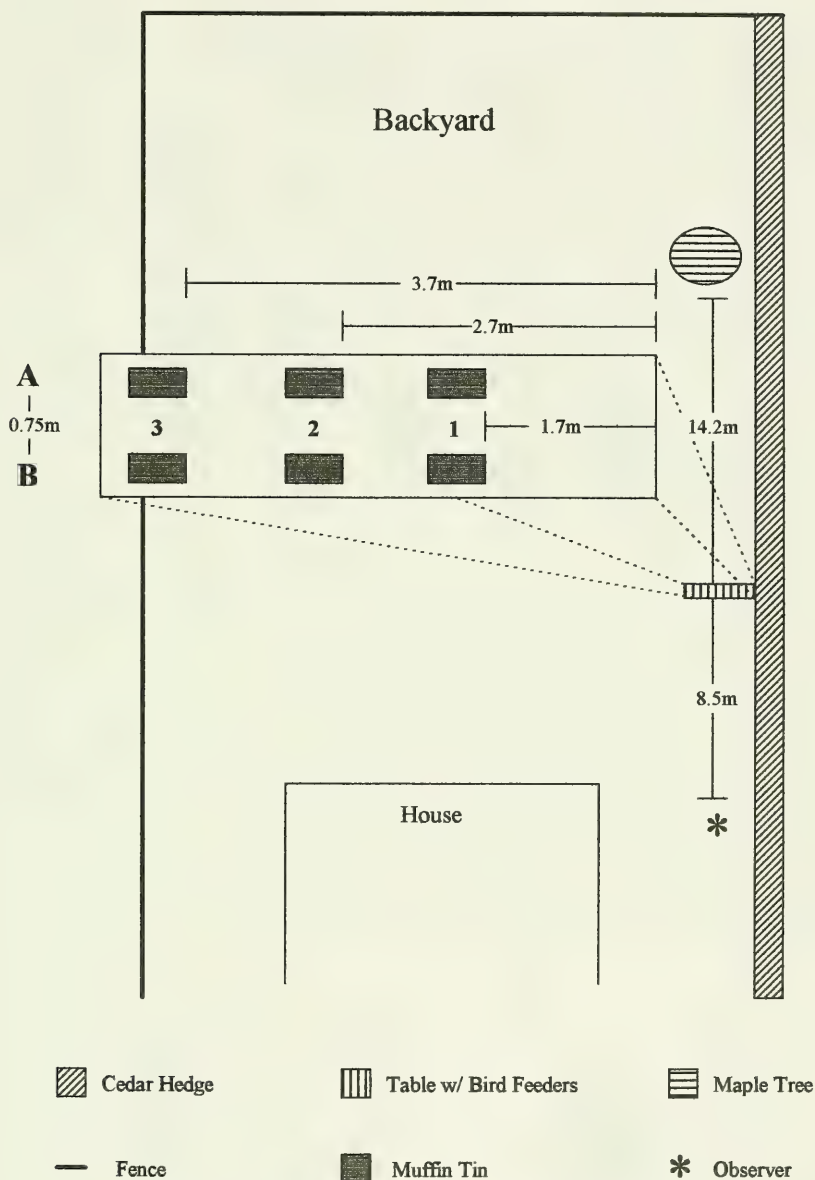


FIGURE 1. Diagram of study location and experimental design.

Materials and Methods

Our study was conducted from 17 October 1995 to 22 January 1996 in a suburban backyard (29 m by 34 m) in London, Ontario. The yard contained a large maple tree (*Acer* sp.), several smaller trees, and a dense row of cedar trees (*Thuja* sp.) growing along a chain link fence. We accustomed a group of birds to the study area by supplying them with black sunflower seeds two weeks prior to commencement of the study.

Three feeding stations were set up perpendicular to and 1.7 m (Station 1), 2.7 m (Station 2), and 3.7 m (Station 3) respectively, from the row of cedar trees (Figure 1). Each feeding station contained two feeders that were 20 cm apart. The three feeders closest to the house (8.2 m away) were designated B feeders, and the other three feeders were designated A feeders; A feeders were closest to the large maple tree (Figure 1). The observer was positioned near the house, 8.5 m from the B feeders (Figure 1). Each

feeder was constructed from a six cup aluminum muffin pan, painted black with non-toxic paint and nailed to a piece of plywood. Holes were made in the bottom of each pan to allow drainage. The six feeders were placed on a picnic table that was extended by addition of a 1.2 m piece of plywood. The feeders were kept full of black sunflower seeds between observation periods.

Data were collected during 34 thirty-minute observation periods, each on a different day. Observations were made at various times of the day. At the beginning of each observation period, 10 black sunflower seeds were placed in each muffin cup so that each feeder contained 60 seeds. During an observation period, the species, position, and number of individuals at each feeder were recorded every 30 seconds. An observation period began when the first bird began feeding. At the end of the observation period, the number of seeds remaining in each feeder was recorded. Ambient temperature, wind speed, and time of day were also recorded.

The number of bird observations recorded at each feeding station during the 34 observation periods were summed for each feeding station, and each feeder. We used chi-square analysis to test whether distance to cover was independent of foraging location of the birds. Data were further divided by species to see if there was interspecific variation in foraging location. To determine, by species, if the birds' feeding location changed over time, each observation period was divided into three 10-minute time intervals and the data for each interval were summed for all the observation periods. Chi-square analysis was used to test whether foraging location was independent of time. If the chi-square test

TABLE 1. Total number and percentage of total observations of seven species of birds at six feeders during 34 thirty-minute observation periods from 17 October 1995 to 22 January 1996.

Species	Observations	%
House Sparrow	1434	66
Northern Cardinal	252	12
House Finch	194	9
Dark-eyed Junco	67	3
White-crowned Sparrow	65	3
Black-capped Chickadee	42	2
Red-breasted Nuthatch	25	1
Total*	2079	96

*The remaining 4% were Blue Jays, Mourning Doves, Rock Doves, and European Starlings.

revealed lack of independence ($P < 0.05$), the data were visually inspected to determine which feeding station the birds moved to during the latter time intervals of the observation period. Using a General Linear Models procedure (GLM; Minitab 1996), we tested for main effects and all interactions between day, station, and feeder on mean number of seeds consumed. Non-significant interactions were excluded from the model. A Tukey's *a posteriori* means test was used to determine which of the six feeders had different mean seed consumption. Significance levels for all tests were set at $P \leq 0.05$.

Results

Ambient temperature and wind speed varied markedly over the study period (17 October-22 January) as did total seed consumption during a 30-

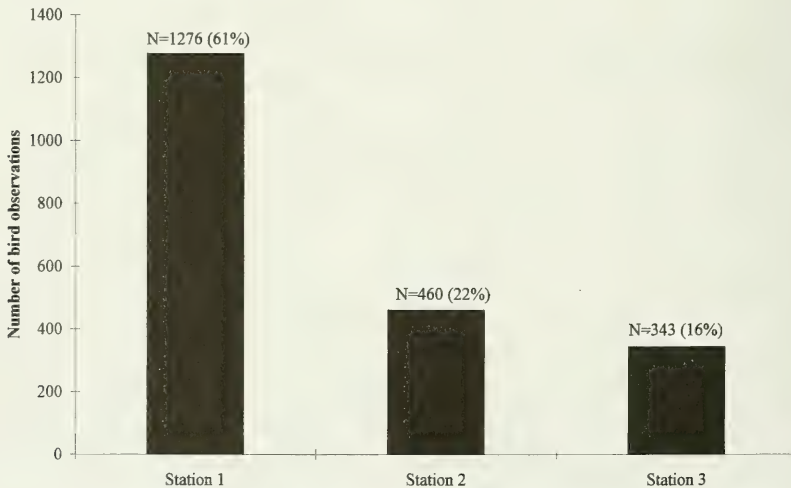


FIGURE 2. Total observations on seven bird species at each of the three feeding stations during 34 thirty-minute observation periods from 17 October 1995 to 22 January 1996.

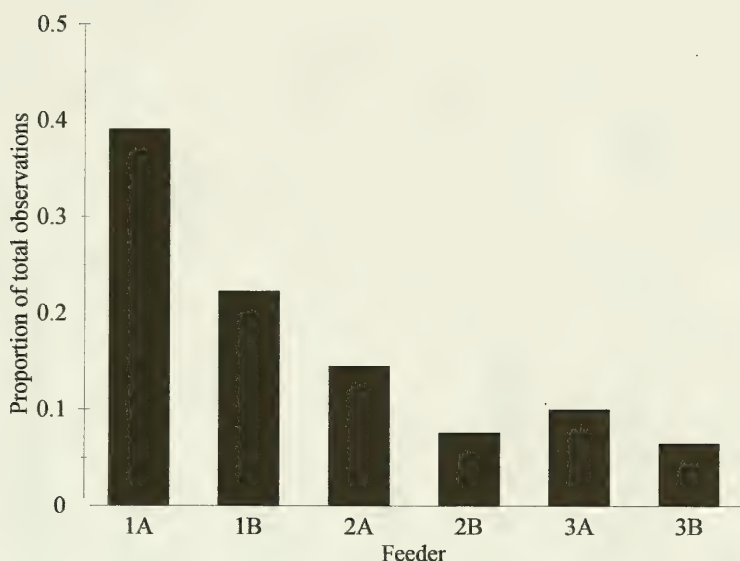


FIGURE 3. Proportion of total observations on seven bird species at each of the six feeders during 34 thirty-minute observation periods from 17 October 1995 to 22 January 1996.

minute observation period (Range = 7–302 seeds). Regression analysis, however, revealed no relationship ($P > 0.05$) between total seed consumption and either ambient temperature or wind speed.

A total of 2172 observations of foraging birds was recorded. Blue Jays (*Cyanocitta cristata*), Mourning

Doves (*Zenaida macroura*), Rock Doves (*Columba livia*), and European Starlings (*Sturnus vulgaris*) were rare visitors to the feeders, and were dropped from all analyses (Table 1). House Sparrows were by far the most frequent visitors to the feeders, followed by Northern Cardinals, House Finches, White-

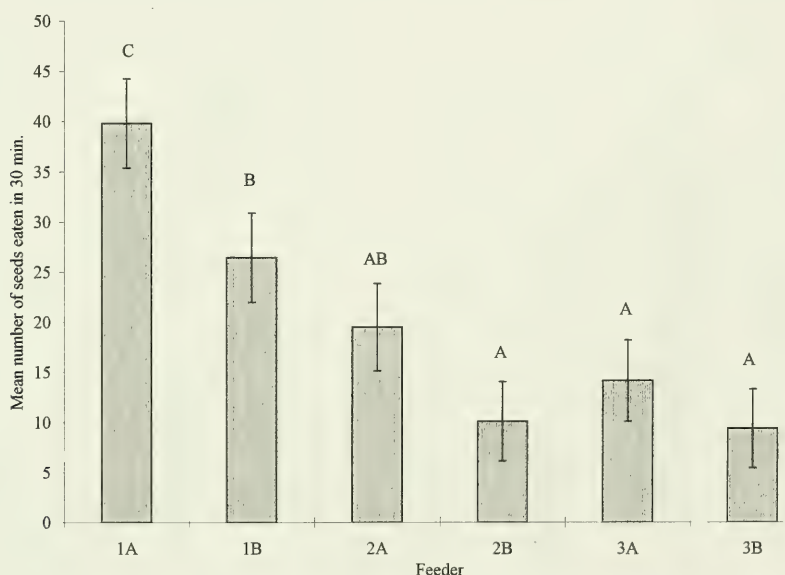


FIGURE 4. Mean (\pm SE) number of seeds consumed at each of the six feeders during 34 thirty-minute observation periods from 17 October 1995 to 22 January 1996. Bars with dissimilar letters are different ($P < 0.05$).

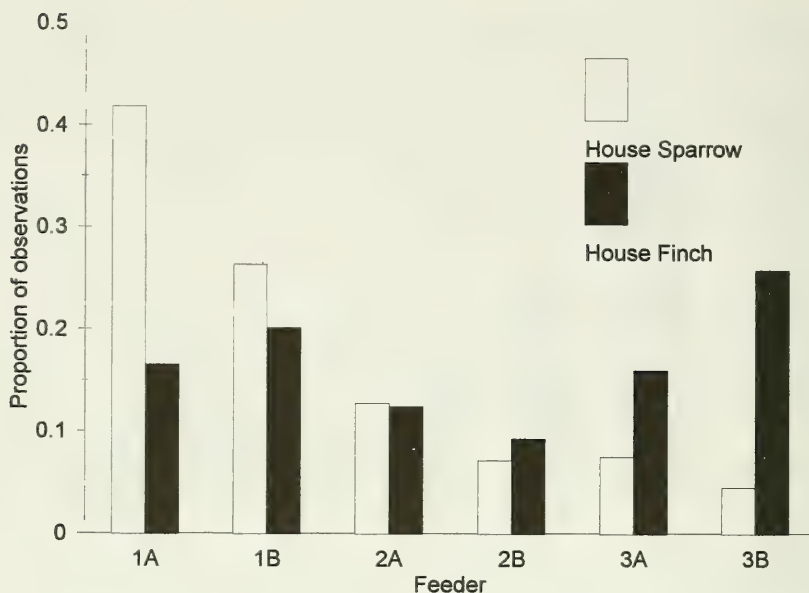


FIGURE 5a. Proportion of total observations on House Sparrows and House Finches at each of the six feeders during 34 thirty-minute observation periods from 17 October 1995 to 22 January 1996.

crowned Sparrows, Dark-eyed Juncos, Black-capped Chickadees, and Red-breasted Nuthatches (Table 1).

As a group, the birds exhibited a strong tendency to feed at station one ($\chi^2 = 745.57$, $df = 2$, $P < 0.001$) (Figure 2). When the total observations were divided

among the six feeders, significantly more observations were made at the A feeder than the corresponding B feeder ($\chi^2 = 94.91$, 43.83 , and 15.53 , $df = 1$, $P < 0.001$, respectively). Out of the total observations, 38% were at feeder 1A, 21% at 1B, 15% at 2A, 9% at 2B, 10% at 3A, and 7% at 3B (Figure 3).

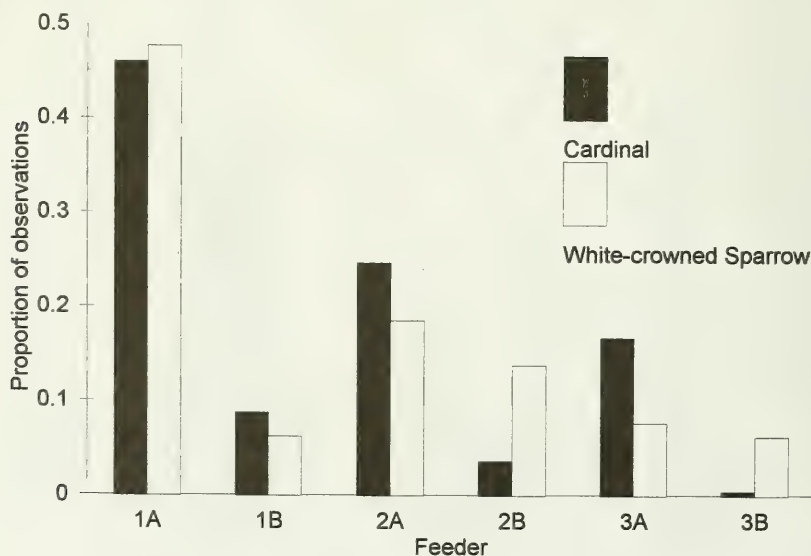


FIGURE 5b. Proportion of total observations on White-crowned Sparrows and Northern Cardinals at each of the six feeders during 34 thirty-minute observation periods from 17 October 1995 to 22 January 1996.

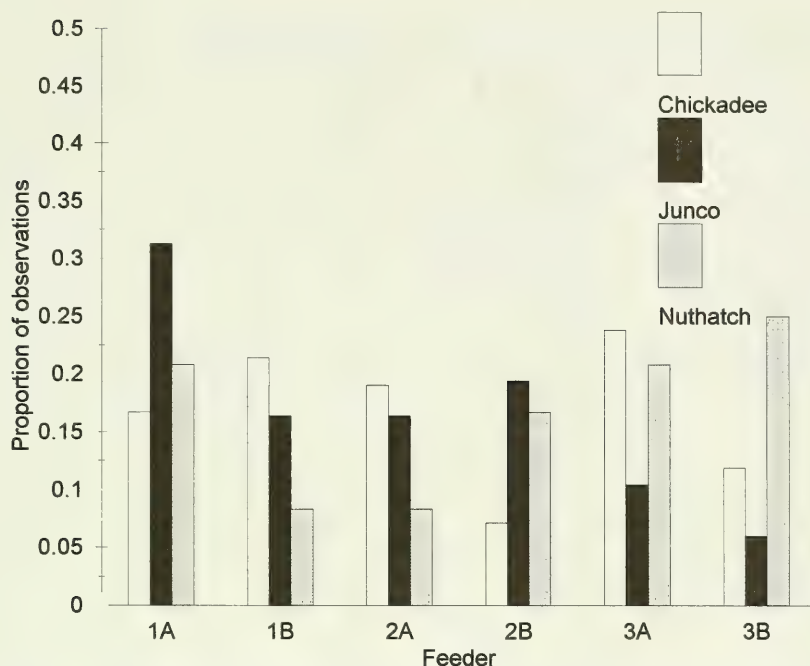


FIGURE 5c. Proportion of total observations on Dark-eyed Juncos, Black-capped Chickadees, and Red-breasted Nuthatches at each of the six feeders during 34 thirty-minute observation periods from 17 October 1995 to 22 January 1996.

Seed Consumption

Mean numbers of seeds consumed differed significantly among observation periods ($F = 9.10$, $df = 30$, $P = 0.0001$), stations ($F = 61.05$, $df = 2$, $P = 0.0001$) and feeders ($F = 28.92$, $df = 1$, $P = 0.0001$). Seed consumption at feeder 1A was significantly higher than at all other feeders (Tukey's test, $P < 0.05$) (Figure 4). Consumption at feeder 1B differed significantly from that at all other feeders except 2A (Tukey's test, $P < 0.05$) (Figure 4). Feeders 2A,B and 3A,B did not differ in amount of seeds consumed (Tukey's test, $P > 0.05$). Seed consumption was consistently higher at A feeders, but the difference was only significant between feeders 1A and 1B (Tukey's test, $P < 0.05$).

Interspecific Variation

House Sparrows, Northern Cardinals, and White-crowned Sparrows exhibited a strong preference to feed close to cover ($\chi^2 = 915.56$, 215.38 , and 49.75 , $df = 5$, $p < 0.001$, respectively) (Figure 5a,b). House Sparrows foraged more frequently at feeders 1A and 1B (Figure 5a). Northern Cardinals also tended to forage closest to cover and showed a marked tendency to feed at the A feeders; 87% of the total Northern Cardinal observations were at A feeders (Figure 5b). White-crowned Sparrows were observed most frequently at feeder 1A, followed by feeder 2A and, overall, were observed more frequently at A feeders (74% of observations) (Figure 5b).

Dark-eyed Juncos foraged close to cover and at feeder 1A most often ($\chi^2 = 15.11$, $df = 5$, $P < 0.05$). However, Juncos did not exhibit as strong a preference for feeder 1A as House Sparrows, Cardinals, and White-crowned Sparrows did (Figure 5c). Juncos showed no preference between feeders 1B, 2A, and 2B, and feeding station three was least utilized (Figure 5c).

House Finches were observed most frequently at feeder 3B, but no obvious pattern was observed in their use of the other five feeders ($\chi^2 = 19.61$, $df = 5$, $P < 0.005$) (Figure 5a). House Finches showed no difference in their use of A and B feeders (Figure 5a). Foraging by Black-capped Chickadees and Red-Breasted Nuthatches was random with respect to feeder location ($\chi^2 = 4.86$ and 3.50 , $df = 5$, $P > 0.05$, respectively) (Figure 5c).

Changes in Foraging Location Over 30 Minutes

Foraging House Sparrows used feeding stations 2 and 3 proportionately more in the latter two time intervals ($\chi^2 = 56.46$, $df = 4$, $P = 0.001$) (Table 2). House Finches also used feeding station 3 far more, and station 1 less, during the last 10 minutes of an observation period ($\chi^2 = 33.56$, $df = 4$, $P = 0.001$) (Table 2). White-crowned Sparrows used station 2 at a higher percentage in the third 10 minutes, but, their use of station 3 decreased ($\chi^2 = 15.45$, $df = 4$, $P = 0.004$) (Table 2).

TABLE 2. Percentage of total observations of seven species of birds at each of the six feeders during 34 thirty-minute observation periods from 17 October 1995 to 22 January 1996.

Species	Time Period	Feeder		
		1A & 1B	2A & 2B	3A & 3B
House Sparrow	0–10 min.	78	15	6
	11–20 min.	64	22	14
	21–30 min.	58	25	17
House Finch	0–10 min.	59	18	24
	11–20 min.	32	21	47
	21–30 min.	10	22	69
White-crowned Sparrow	0–10 min.	60	11	29
	11–20 min.	27	55	18
	21–30 min.	55	45	0
Northern Cardinal	0–10 min.	58	24	18
	11–20 min.	40	37	23
	21–30 min.	64	23	12
Black-capped Chickadee	0–10 min.	53	40	7
	11–20 min.	31	25	44
	21–30 min.	41	24	35
Red-breasted Nuthatch	0–10 min.	38	13	50
	11–20 min.	40	40	20
	21–30 min.	17	33	50
Dark-eyed Junco	0–10 min.	56	24	20
	11–20 min.	60	40	0
	21–30 min.	27	45	27

Northern Cardinals, Black-capped Chickadees, and Red-breasted Nuthatches did not significantly alter their foraging distribution during the 30-minute observation periods ($\chi^2 = 8.70$, $df = 4$, $P = 0.064$; $\chi^2 = 5.78$, $df = 4$, $P = 0.322$; $\chi^2 = 2.95$, $df = 4$, $P = 0.566$; respectively) (Table 2). Dark-eyed Juncos fed more at stations 2 and 3 during the last 20 minutes, but the difference was only marginally significant ($\chi^2 = 9.62$, $df = 4$, $P = 0.047$) (Table 2).

Discussion

Overall, we found that four species of birds showed strong preferences for feeding close to escape cover, two species showed no preference, and one species showed a slight tendency to forage away from cover. Generally, when food became depleted, birds sacrificed predation exposure by feeding farther from cover. Similar results were found by Suhonen (1993) when Crested Tits (*Lophophanes cristatus*) fed closer to tree trunks during a winter with relatively high predation risk. Schneider (1984) and Slotow and Rothstein (1995) demonstrated that White-crowned Sparrows fed closer to cover when offered a choice between foraging sites.

House Sparrows and White-crowned Sparrows used the cedar hedge between foraging bouts and foraged most frequently at feeder 1A. Sparrows also preferred A feeders over the B feeders. Typically, a House Sparrow would alight on either the chain link

fence or in the cedar trees. It usually would be joined by other House Sparrows before flying down to feed at the closest feeder and when startled would immediately flee into the cedars. Elgar (1987) also observed House Sparrows foraging in this manner. White-crowned Sparrows also utilized the cedars as a source of cover, but they usually foraged solitarily. Northern Cardinals did not use the cedar trees for perching, but instead used the maple tree, and sometimes, an evergreen tree in a neighbouring yard. The first Northern Cardinal to arrive in the tree waited to be joined by conspecifics before flying down to feed. It was common to see 20 Northern Cardinals, including 5 to 7 males, in the tree at one time. Northern Cardinals' use of these trees as a perch site may explain their preference for feeding at the A feeders as the trees were on the "A side" of the feeding stations. Regardless, it seems likely that birds overall preferences for A feeders (Figure 3) was at least partly because they were farther from the observer (Figure 1) and the birds may have perceived the observer as a threat and foraged farther away to reduce risk of predation.

Although House Finches used the cedar hedge as a source of cover, they foraged most at station 3. Valone and Lima (1987) also observed House Finches feeding farther from cover than other bird species. To benefit from feeding away from cover, an extra energy return must be obtained to compen-

sate for the increased risk associated with foraging at a risky site (Todd and Cowie 1990). By feeding farther from cover on food not depleted by other birds, the House Finches perhaps derived an energetic advantage. Alternatively, the birds may have been forced to forage farther from cover by the more aggressive House Sparrows (Burke 1983). During our observations, House Sparrows frequently displaced House Finches at the feeders. Observations of House Finches in the absence of House Sparrows would be required to determine which of these explanations is most plausible.

Dark-eyed Juncos foraged most often at feeder 1A, but did not differ in use of feeders 1B, 2A, and 2B. Juncos were commonly observed hopping from one feeder to the next, and did not remain at one feeder for long. Maximal foraging efficiency is obtained by remaining in a patch to feed, thereby obtaining the maximum energy intake per unit of time (Valone and Lima 1987). Possibly, the Juncos, behaviour resulted from their small bills, which likely prevented them from opening sunflower seeds. Thus, they may have been searching for bits of seeds that had been broken up by other birds.

Black-capped Chickadees and Red-breasted Nuthatches did not exhibit preferences in feeding location. This result is explained by how they handle large seeds like those of sunflowers; i.e., both species hold the seed against a perch with a foot and peck it open. Whenever chickadees and nuthatches were observed, they always carried seeds to cover for consumption. The feeder from which they took the seeds appeared to be the one that was closest to the tree that they were perched in before flying down to feed.

House Sparrows and House Finches fed farther from cover more frequently near the end of the 30-minute observation period. This shift in foraging distribution can be at least partly attributed to food depletion in the feeders close to cover. As the food became more scarce, the foraging birds were forced to accept a higher risk of predation to meet their energetic demands. The shift in foraging location may also be due to the "safe" feeders already being occupied when late coming individuals arrived. Schneider (1984), and Slotow and Rothstein (1995), discovered that dominance status influenced the distribution of White-crowned Sparrows among feeders at different distances from cover. Dominant individuals displaced subordinates to feeders farther from cover. Possibly, individuals arriving later in the observation period were forced to feed farther from cover by individuals already present at the close feeders.

One explanation for why a shift in foraging distribution was not observed in all species is that alternative foraging opportunities were already available nearby, i.e., there was a bird feeder in the adjacent yard that was stocked with sunflower seeds. Therefore, upon depletion of the feeders close to

cover in our study area, the birds did not have to venture far to locate another patch of food.

The results of this study suggest that foraging behaviour is influenced by predation risk. However, other factors such as dominance status and interspecific competition could also act on foraging behaviour. Therefore, the behaviour of foraging birds reflects a trade-off between these forces. By foraging in a habitat that effectively reduces predation risk, birds maximize their probability of surviving until the next breeding season. Species that carry food to cover reduce the length of time exposed to predation instead of relying on escaping in the event of an attack. The species investigated in this study used different strategies to minimize predation risk.

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Diets of Norway Rats, *Rattus norvegicus*, on Langara Island, Queen Charlotte Islands, British Columbia: Implications for Conservation of Breeding Seabirds

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Diets of introduced Norway Rats (*Rattus norvegicus*) on Langara Island, Queen Charlotte Islands (Haida Gwaii), British Columbia, were investigated in May–June 1995 to evaluate the role of rats as predators of breeding Ancient Murrelets (*Synthliboramphus antiquus*). We examined the contents of 80 stomachs collected from rats trapped in three areas of the island. Items occurring in high percent volumes (> 50 %) and with highest frequency included plant shoots, Salal berries (*Gaultheria shallon*), amphipods (Arthropoda: Amphipoda), and tissues of Ancient Murrelets. Occurrence and volume of each food type varied positively with their apparent availability on the island. Rats near the coast fed primarily on marine invertebrates, fruits and seeds, whereas rats in interior habitats fed primarily on terrestrial invertebrates and plant shoots. Tissues of Ancient Murrelets occurred with highest frequency (53 % of stomachs examined, $n = 19$) and volume (mean percent volume of stomach: mean = 41 ± 11 % (SE)) in diets of rats trapped in the Ancient Murrelet colony. Along with previous findings of dead adult Ancient Murrelets exhibiting wounds typical of rat predation on seabirds, and murrelet bones found in almost 30% of breeding murrelet burrows, this study implicates introduced Norway Rats as important predators of Ancient Murrelets.

Key Words: Norway Rats, *Rattus norvegicus*, diet, Ancient Murrelets, *Synthliboramphus antiquus*, seabird conservation, Langara Island, Queen Charlotte Islands, British Columbia.

The decline of nesting seabirds on Langara Island, at the northwest end of the Queen Charlotte Islands (Haida Gwaii), represents a classic example of seabird declines for the temperate region (Bailey and Kaiser 1993; Bertram 1995). Surveys of Ancient Murrelets indicated the original population of approximately 200 000 breeding pairs (Gaston 1992) decreased to 80 000–90 000 in 1971, to $21\,740 \pm 3570$ (SE) in 1981, to $24\,000 \pm 6250$ (SE) in 1988, and to $14\,630 \pm 2060$ (SE) in 1993 (Bertram 1995). The disappearance of breeding populations of Cassin's Auklets (*Ptychoramphus aleuticus*), Rhinoceros Auklets (*Cerorhinca monocerata*), Fork-tailed Storm-Petrels (*Oceanodroma furcata*), and Leach's Storm-Petrels (*O. leucorhoa*), has accompanied this decline (Rodway et al. 1983). A small colony of Tufted Puffins (*Fratercula cirrhata*) remains on nearby Cox Island (Vermeer et al. 1984; Campbell et al. 1990), and Pigeon Guillemots (*Cepphus columba*) continue to breed on a large boulder with strongly recurved sides on the south part of Langara Island (Bailey and Kaiser 1993).

Introduced rats (*Rattus* spp.) have negatively impacted seabird populations throughout the world (Moors and Atkinson 1984), but their exact role on Langara Island was obscured by confounding factors, including mortality of birds in gill nets in adjacent waters, reduced food supply due to commercial

fishing, zooplankton declines, toxic chemicals, and avian predators (Nelson and Myers 1976; Sealy 1976; Bertram 1995). Bertram (1995) found dead adult Ancient Murrelets with wounds at their napes, typical of rat predation on seabirds (Moller 1983). Furthermore, he found murrelet bones in almost 30% of breeding murrelet burrows. Skeletal remains were most common in abandoned areas of the seabird colony and were least common in areas where burrows remained occupied (Bertram 1995). Previous researchers dismissed the importance of rats in the decline of the Ancient Murrelets, citing that rats had been present long before the observed decline (Nelson and Myers 1976; Sealy 1976). However, the Norway Rat (*Rattus norvegicus*) has recently replaced the Black Rat (*Rattus rattus*) previously found on Langara Island (Taylor 1993*; Bertram 1995; Bertram and Nagorsen 1995). Norway Rats are 1.5 times heavier than adult Ancient Murrelets (Bertram 1995). Because of its large size and burrowing habits, the Norway Rat is a greater threat to breeding seabirds than the Black Rat (Moors and Atkinson 1984). Furthermore, the arrival of the Norway Rat coincides more closely with the extinction of the seabird colonies and also with the appar-

*See Documents Cited section

ent disappearance of the Deer Mouse (*Peromyscus maniculatus*) (Taylor 1993*).

Recent developments have made timely eradication of rats a viable management option for conservation of island birds (Taylor and Thomas 1993; Kaiser et al. 1997). The food habits of Norway Rats on Langara Island are relevant to an eradication campaign. First, baited traps or poison must compete with other food sources. Knowing what rats eat can help to time an eradication campaign effectively. Second, in the absence of predators of rats on Langara Island, availability of food likely limits numbers and distribution of rats. Thus, information on diet of rats can aid in weighting a poison baiting system so that areas with abundant food sources receive more bait than areas where food is less abundant. Third, the diet of rats can provide evidence of movement and foraging ranges of rats; e.g., marine foods found in stomachs of inland rats. Fourth, diet information, obtained by examining stomach contents, can assuage sceptics by providing direct evidence of rat predation on the island's bird populations.

Study Area

We conducted the study on Langara Island (3253 ha), near the northwest tip of the Queen Charlotte Islands (Haida Gwaii), British Columbia (54°12'N, 133°01'W). This island lies in the Coastal Western Hemlock biogeoclimatic zone, central very wet hypermaritime variant (CWHvh2), characterised by a cool climate, very little snowfall, and fog, cloud, and drizzle common throughout the year (Green and Klinka 1994). The terrain of Langara Island is relatively flat, with cobble and sand beaches on the east and south sides and steep cliffs to the north and west. It also has several small inland lakes and permanent streams. The island has four major forest habitat types in concentric bands. Old-growth Sitka Spruce (*Picea sitchensis*) with an understorey of Nootka Reed-Grass (*Calamagrostis nutkaensis*) grows in a band along the coast, with scattered patches of dense spruce regeneration (Spruce habitat). Western Hemlock (*Tsuga heterophylla*) grows further inland with Salal (*Gaultheria shallon*) or moss as the predominant understorey (Hemlock habitat). Further inland, Western Hemlock is gradually replaced by Western Redcedar (*Thuja plicata*) which forms the Redcedar habitat type. Salal or moss occurs beneath the Redcedars depending on local soil moisture. The fourth major habitat type consists of extensive bogs that cover the centre of the island and contain Common Juniper (*Juniperus communis*) and Shore Pine (*Pinus contorta* v. *contorta*) (Interior habitat).

The study focused on three areas on Langara Island: the Ancient Murrelet colony, the South End, and Hazardous Cove. The Ancient Murrelet colony occupies the northeast corner of the island and extends 1900 m westward from MacPherson Point,

with a smaller section of 50 burrows on Explorer Bay (Harfenist 1994). Ancient Murrelets nest in burrows and begin breeding in April each year, and most finish breeding by mid-June (Gaston 1992). The South End includes Henslung Cove and Dadens. This area receives the heaviest human traffic and contains several land-based and floating fishing lodges. Two lodges have luxury accommodations for guests on the island, and the remainder house their guests on barges or boats moored in the cove. The fishing season begins in May and continues until late September. The third area, Hazardous Cove, on the southwest side of Langara Island, contains several dense thickets of Salal. During low tides, an extensive littoral zone becomes exposed that could serve as an rich source of food for Norway Rats. Most other shorelines on the island are steep and have a near-vertical or narrow littoral zone.

Methods

Norway Rats were killed in snap traps at six sites on Langara Island between April and July 1995. Two snap-trapping sites were chosen in the seabird colony (No Name Point and McPherson Point), two on the South End (Henslung Cove and Dadens), and two near Hazardous Cove (Hazardous Cove East and Hazardous Cove West) (Figure 1). At each site, three trap lines were established, each 400 m long and consisting of 16 traps spaced 25 m apart. The trap lines ran parallel to the shoreline, and each line sampled one of three habitat types (Spruce, Hemlock, or Redcedar). The trap lines were 25 to 200 m apart at each site depending on the width of the habitat. Each site was sampled twice, for three nights each in May and June, using snap traps baited with a mixture of

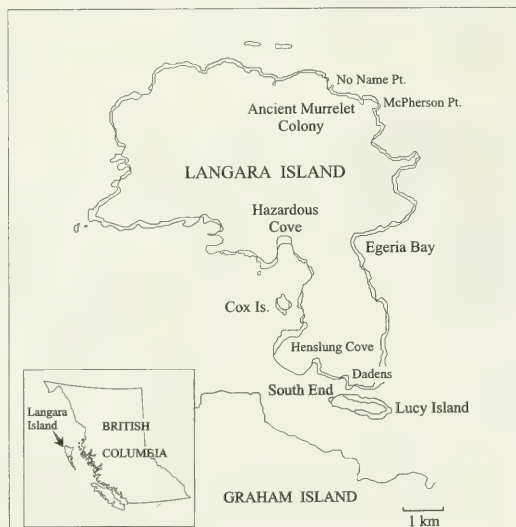


FIGURE 1. Map of Langara Island and sampled areas.

rolled oats and peanut butter. A third trapping session was conducted in early July in the Ancient Murrelet colony, after most murrelets had finished breeding and had left the island.

The stomachs of trapped rats were removed, and preserved at -10°C . Under a dissecting microscope, stomach contents were identified to food type using a reference collection gathered from the field and from the natural history collection at Simon Fraser University. Feathers were identified following the general approach of Day (1966), by examining downy barbules under a light microscope and comparing them to a reference specimen of an adult Ancient Murrelet collected from the island. Ancient Murrelet feathers had clear bases, tapered pennula, and pigmented internodes. Muscle tissues were considered to be Ancient Murrelet if found with Ancient Murrelet feathers, or if they resembled such tissues. For each stomach, we recorded all food types, visually estimated percent volume of each food type, and placed each type into one of seven groups: fungi, fruits and seeds, plant shoots (including unidentified stem fragments), terrestrial invertebrates, marine invertebrates, fish, and birds.

We compared the frequency of occurrence of different food groups between sexes of rats, as well as among habitats and areas, using Fisher's exact tests for contingency tables larger than 2×2 (Agresti 1996). The volumes of food groups were compared using an approximation of the Kruskal-Wallis test by applying an ANOVA procedure to ranks of the data (Zar 1996). To offset the probability of spurious significance resulting from the large number of tests, we used a Bonferroni-adjusted significance level ($\alpha = 0.01$) to maintain an overall significance level of 0.05 for comparisons between sexes, among habitats, and among areas (Zar 1996). Due to confusion with labelling, six stomachs could not be reliably assigned to an area or habitat, and five stomachs had no contents (see Results). Therefore, only 69 stomachs were considered in comparisons among areas and habitats.

Results

We identified 34 food types in 80 rat stomachs (Table 1). Some food types in advanced stages of digestion (7.5%) could not be identified. Five stomachs were empty, 22 stomachs contained only one food type, and some contained up to six food types (mean = 2.31 ± 0.17 (SE) types per stomach, $n = 80$). Overall, food types that occurred in high frequencies and volumes included plant shoots, Salal berries, Sitka Spruce seeds, amphipods, and parts of Ancient Murrelets (Figure 2; Table 1).

The percent occurrence and volume of each food group did not differ between males ($n = 39$) and females ($n = 41$) (Fisher's exact test and Kruskal-Wallis test, $P > 0.01$ for all tests). With the exception of birds, plant shoots, and terrestrial invertebrates, the occurrence and percent volume of food groups did

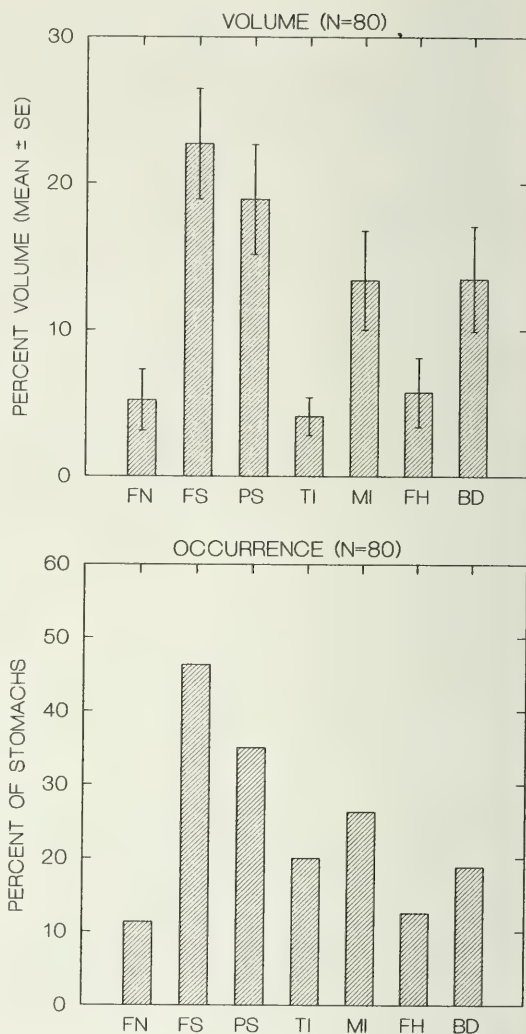


FIGURE 2. Percent occurrence and percent volume of food groups in stomachs of Norway Rats (*Rattus norvegicus*) trapped between April and July 1995 on Langara Island, British Columbia. Food groups are: FN, fungi; FS, fruits and seeds; PS, plant shoots; TI, terrestrial invertebrates; MI, marine invertebrates; FH, fish; BD, birds.

not vary with the habitat and area in which the rats were trapped (Figures 3, 4). Rats from the Ancient Murrelet colony ate birds with higher frequency and in higher volumes than rats from the South End and Hazardous Cove (occurrence: Fisher's exact test, $P < 0.01$; volume: $F = 35.9$, $df = 2,63$, $P < 0.01$; Figure 3). Bird parts were primarily muscle and skin tissue from adult Ancient Murrelets, although feathers from an unidentified bird species were found in two stomachs from rats in the South End. In particular, tissues of Ancient Murrelets were found in 53% of stomachs from 19 rats trapped in the Ancient Murrelet colony,

TABLE 1. Occurrence and volume of food types in stomachs of 80 Norway Rats (*Rattus norvegicus*) trapped on Langara Island, British Columbia. Food types are listed in decreasing order of occurrence within groups.

Food Group	Food type	Number of stomachs containing food type	Number of stomachs by percent volume of contents		
			Low (< 10%)	Medium (10–50%)	High (> 50%)
Fruits and seeds	Salal	17	0	9	8
	Sitka Spruce	9	2	4	3
	Sedge (<i>Carex</i> spp.)	3	0	4	2
	Red Huckleberry (<i>Vaccinium parvifolium</i>)	3	3	0	0
	Nootka Reed-Grass	2	2	0	0
	Western Hemlock	2	1	0	1
	Rush (<i>Juncus</i> spp.)	1	1	0	0
Plant shoots	Unidentified	21	3	6	12
	Western Hemlock	7	5	2	0
	Sitka Spruce	3	3	0	0
	Rush	3	2	0	1
	Moss	2	1	1	0
	Red Huckleberry	1	0	1	0
	Western Redcedar	1	1	0	0
	Pacific Yew (<i>Taxus brevifolia</i>)	1	1	0	0
	Red Alder (<i>Alnus rubra</i>)	1	1	0	0
	Algae	1	1	0	0
Fungi	Unidentified	8	1	3	4
Terrestrial invertebrates	Crickets (Orthoptera: Gryllidae)	6	2	4	0
	Millipede (Arthropoda: Diplopoda)	2	0	2	0
	Weevil (Coleoptera: Curculionidae)	1	1	0	0
	Carabid (Coleoptera: Carabidae)	1	1	0	0
	Land Snail (<i>Haplotrema sportella</i>)	1	1	0	0
	Mayfly (Ephemeroptera)	1	1	0	0
Marine invertebrates	Amphipods (Arthropoda: Amphipoda)	15	4	3	8
	Crabs (Arthropoda: Decapoda)	4	1	3	0
	Mussels (Mollusca: Bivalvia)	3	0	2	1
	Snail (Mollusca: Gastropoda)	1	0	1	0
Fish	Scales	6	3	2	1
	Flesh	3	0	0	3
	Roe	2	1	0	1
Birds	Ancient Murrelet	15	1	5	9
	Unidentified	2	2	0	0

and on average, constituted 41% of the volume of these stomachs. Rats from the Ancient Murrelet colony also ate fewer plant shoots than did rats from other areas (Fisher's exact test, $P < 0.01$). The percent occurrences of plant shoots and terrestrial invertebrates were greater in the diets of rats from the Hemlock and Redcedar habitats than in the diet of rats from Spruce habitat near the coast (plant shoots, Fisher's exact test, $P < 0.01$; terrestrial invertebrates, Fisher's exact test, $P < 0.01$; Figure 4). Three stomachs of rats trapped in inland habitats contained amphipods and three other stomachs of rats from inland habitats contained fish.

Discussion

Norway Rats on Langara Island were true omnivores, feeding on a wide diversity of food types.

This dietary plasticity is a fundamental aspect of rat feeding behaviour, and has been documented in wild rat populations throughout islands of the world, including New Zealand, Hawaii, South Georgia, and the Galapagos (Pye and Bonner 1980; Clark 1981; Moors 1985; Amarasekare 1994). Norway Rats appear to exploit the highest quality and most readily available food items of each area and habitat. For example, the incidence of plant shoots in rat diets increases with distance from the ocean (Figures 3, 4), which suggests that near the ocean other foods were available and readily eaten. In addition, terrestrial invertebrates, which are higher in protein and have a greater variety of essential amino acids than most plants (Needham 1964; Clark 1981; Moors 1985), were consumed in greater frequencies and volumes in the inland habitats. Near the coast, amphipods and

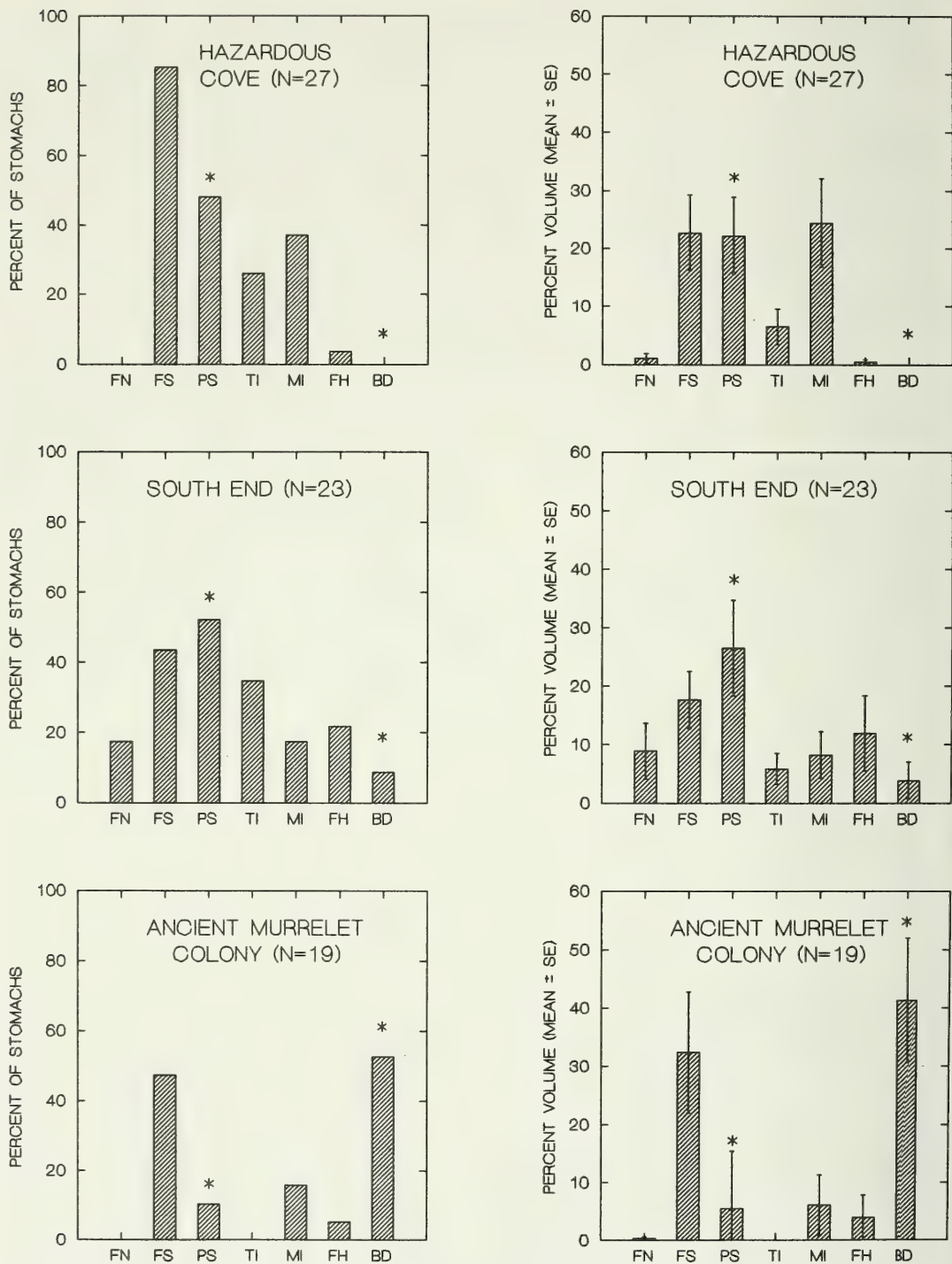


FIGURE 3. Percent occurrence and percent volume of food groups in stomachs of Norway Rats (*Rattus norvegicus*) trapped between April and July 1995 in three areas on Langara Island, British Columbia. Food groups: FN, fungi; FS, fruits and seeds; PS, plant shoots; TI, terrestrial invertebrates; MI, marine invertebrates; FH, fish; BD, birds. Percents with asterisks are significantly different in occurrence (Fisher's exact test, Bonferroni adjusted significance level, $P < 0.01$) or volume (Kruskal-Wallis test, Bonferroni adjusted significance level, $P < 0.01$) among areas.

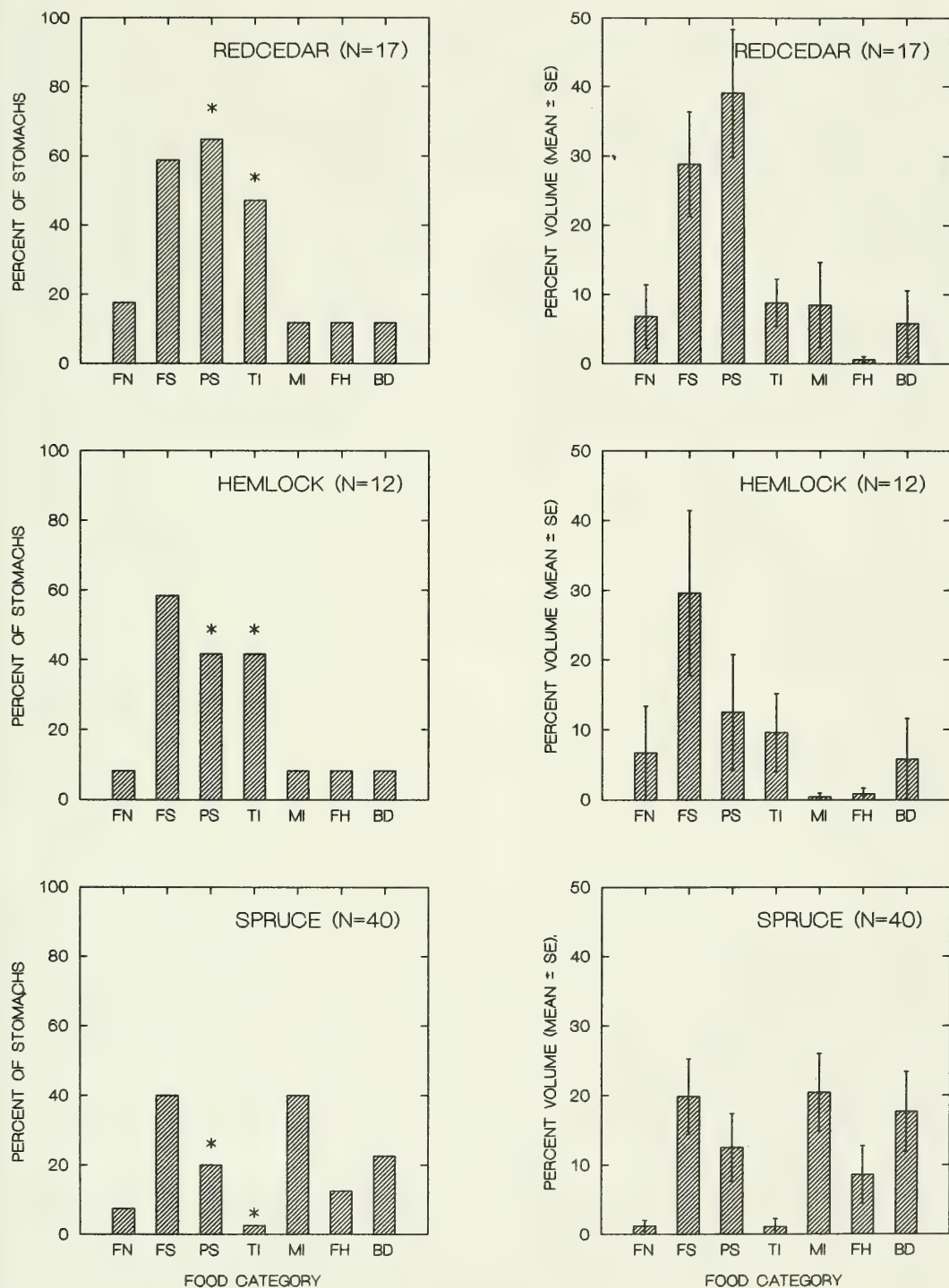


FIGURE 4. Percent occurrence and percent volume of food groups in stomachs of Norway Rats (*Rattus norvegicus*) trapped between April and July 1995 in three habitats on Langara Island, British Columbia. Spruce habitat lies near the coast of the island. Hemlock and Redcedar habitats are in the interior of the island. Food groups: FN, fungi; FS, fruits and seeds; PS, plant shoots; TI, terrestrial invertebrates; MI, marine invertebrates; FH, fish; BD, birds. Percents with asterisks are significantly different in occurrence (Fisher's exact test, Bonferroni adjusted significance level, $P < 0.01$) or volume (Kruskal-Wallis test, Bonferroni adjusted significance level, $P < 0.01$) among habitats.

other marine invertebrates provide much of this protein. Several species of amphipods are nocturnal, feed in large masses on vegetation at or near the high-tide line on exposed beaches (Kozloff 1993), and thus are available when rats are most active.

Most of the unidentified partially digested plant shoots in the stomachs were probably Salal. During spring and early summer, we often found Salal with the growing tips removed, and the distribution of rats was positively associated with percent cover of Salal (Drever 1997). The frequent occurrence and high volume of plant material in the stomachs suggested that plants were staple foods of rats on Langara Island, as they are on islands elsewhere (Wirtz 1972; Pye and Bonner 1980; Clark 1981; Moors 1985; Taylor and Thomas 1993; Amarasekare 1994). The importance of seeds and shoots in the diet of rats on Langara Island implies that a poison campaign during winter, when these foods are least available, would likely maximise uptake of poison baits. However, stormy weather during winter creates a high hazard for human access, and the large manpower needs of a project this size precluded a winter campaign (Kaiser et al. 1997).

The presence of amphipods in stomachs of three rats from inland habitats up to 500 m from the coast suggested that rats forage widely, and at least some inland rats reach the littoral zone occasionally. Two of these rats were males, which are known to move long distances on other islands (Taylor and Thomas 1993). The presence of fish in the stomach of inland rats does not necessarily reveal long-range movement, because Bald Eagles (*Haliaeetus leucocephalus*) and other scavengers often drop large pieces of their prey inland, thus making them available to rats.

It is impossible to differentiate from stomach contents if rats had fed from carrion or from birds which they had killed. However, the high frequency and volumes of tissues of Ancient Murrelets found in stomachs from rats trapped in the Ancient Murrelet colony, in addition to dead adult birds with wounds at their nape and the high proportion of murrelet burrows with bones (Bertram 1995), suggest that rats prey on murrelets directly rather than scavenge them. Moreover, the reduced occurrence of plant material in the diet of rats trapped in the murrelet colony suggests rats in the colony were feeding preferentially on murrelets. Because most of the rats from the seabird colony were trapped in July, after the majority of Ancient Murrelets had finished breeding (Gaston 1992), the data presented here may underestimate the importance of Ancient Murrelets in the diet of rats on Langara Island. Subsequent analysis of carbon and nitrogen stable isotopes in the livers and muscle tissues of rats later confirmed this underestimation (Drever 1997; Hobson et al. *in press*).

Bertram (1995) focused on rats as the primary contributors to the decline of Ancient Murrelets on

Langara Island because he could find little evidence for the continuing role of the other two hypothetical causes: reduced zooplankton production, and fatal light attraction and drowning of birds during commercial fishing operations during the 1950s and 1960s. Plankton production has shown no consistent decline since 1957 (Bertram 1995). Historical commercial fishing likely killed large numbers of Ancient Murrelets prior to the 1970s, although murrelets continued to decline following the disbandment of this large salmon-fishing fleet (Bertram 1995). Perhaps fishing operations brought the murrelet population down to a level that it could no longer sustain predation by rats. Between 1988 and 1993, the nesting population of Ancient Murrelets declined from 24 250 nesting pairs to 14 630 nesting pairs (Harfenist 1994). Thus, assuming a constant decline, 9620 pairs disappeared over five years at a rate of 1924 pairs per year, or 3848 individual birds per year, which approximates 43 birds per day over the 90-day period from mid-April to mid-June during which Ancient Murrelets breed on the island (Gaston 1992). Over this time, the colony area contracted from 46.3 ha to 22.9 ha (Harfenist 1994). Using an mid-range value of 35 ha, and an average density of rats of three rats per ha in the seabird colony (Kaiser et al. 1997), we estimate that a population of 105 rats was eating nesting murrelets at a rate of one murrelet per rat every 2.4 days. This estimate attributes all murrelet disappearances to direct predation by rats, and does not consider the murrelets abandoning the colony to nearby rat-free colonies on Frederick and Forrester Islands. Thus, it seems plausible that rats were responsible for the decline of Ancient Murrelets on Langara Island.

This study, along with other evidence collected by Bertram (1995), implicates Norway Rats as important predators of Ancient Murrelets. Using funds acquired from the litigation settlement of the Nestucca oil spill, the Canadian Wildlife Service eradicated rats from Langara Island between 1995 and 1997 before the Ancient Murrelet colony disappeared (Kaiser et al. 1997). If rats were responsible for the seabird declines, then the population of Ancient Murrelets should benefit greatly from the reduced predation pressure. Steps must be taken to prevent the re-introduction of rats to Langara Island.

Acknowledgments

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Preliminary Investigation into the Effects of Water-level Control on Seedling Recruitment in Riparian Cottonwoods, *Populus deltoides*, on the South Saskatchewan River

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The demographic characteristics of riparian Plains Cottonwood (*Populus deltoides* Marsh.) stands along the North and South Saskatchewan Rivers near Saskatoon were compared to determine if the operation of the Gardiner Dam on the South Saskatchewan River has affected establishment of this species. Prior to construction mean river discharge upstream and downstream from the dam was 1281 and 1498 m³ s⁻¹ respectively; this subsequently decreased to 945 and 608 m³ s⁻¹ respectively. Similarly, sediment loads in the South Saskatchewan River for the period 1986-1996 averaged 143.9 mg l⁻¹ above the dam compared to only 12.9 mg l⁻¹ downstream. This change in hydrological regime appears to have reduced the recruitment of cottonwoods along the South Saskatchewan River downstream from the Gardiner Dam compared to the North Saskatchewan River which is regulated only near its source.

Key Words: Cottonwoods, *Populus deltoides*, Gardiner Dam, population recruitment, river discharge, seedling establishment, Saskatoon, South Saskatchewan River.

The Plains Cottonwood (*Populus deltoides* Marsh.) is an important riparian woodland species. It is the dominant tree species in many riverbank communities where it provides shelter and nest sites for birds and small mammals and shady resting sites for some species of fish. Cottonwoods also help to stabilize riverbanks and reduce the flow of nutrients from agricultural lands into the rivers (Risser 1995). In the Canadian prairies the success of the cottonwoods is directly linked to river flow regimes with peak discharge in late spring associated with snowmelt in the Rocky Mountains (Rood and Mahoney 1990). Cottonwoods disperse their seeds as the floodwaters begin to recede. The spring floods recharge the ground water tables, saturate the surface substrates, and transport and deposit new sediments to the outer reaches of the meander lobes (Bridge and Jarvis 1982). Conditions on the floodplain are critical for seedling germination and the established stands of cottonwoods become progressively older with distance from the riverbanks (Bradley and Smith 1986).

The sequence of events of the cottonwood life cycle creates a distinctive pattern of even aged stands parallel to the meander lobes along the river banks, thus providing a record of river channel migration and a history of floodplain events (Everitt 1968). One reproductive strategy of cottonwoods is to produce a large number of seeds just after the spring floods have created beds of fresh, moist sediment. Cottonwoods start to produce seeds in the age range of 5 to 10 years. A single tree can produce up

to 25 million seeds in one season (Johnson et al. 1976). In Saskatchewan the seeds typically are produced and dispersed over a period of 2 to 4 weeks in June. The seeds are small, approximately 1 mm in length, and are attached to cottony enclosures to assist in wind and water dispersal.

Seed dispersal occurs just after the flood waters have subsided. Optimal conditions for seed germination occur on an irregular basis because of annual variation in magnitude of spring floods (Barnes 1985); in the western prairies an interval of 2 to 10 years is suggested (Bradley and Smith 1986). Cottonwood seeds remain viable for approximately 2 to 4 weeks (Fenner et al. 1984; McComb and Lovestead 1954) so seed release must coincide with high moisture content in the freshly deposited or scoured sands and gravels. Typically, many seeds fall into the water, but because of their light weight they do not travel downstream any great distance before being washed ashore. Establishment and subsequent survival of the cottonwood seedlings occurs within certain elevations on the stream bank. The young plants must be high enough above the river to minimize damage from winter ice scour and flooding, but low enough to prevent desiccation during seasonal declines in the water table. Optimal sand and gravel soils are no more than 4 meters above the water level (McBride and Strahan 1984).

Once the seeds are established, growth is rapid. Seedlings can reach an above ground height of 30 cm in the first year and up to 50 cm in the second year (Akashi 1988). A high seedling mortality rate is

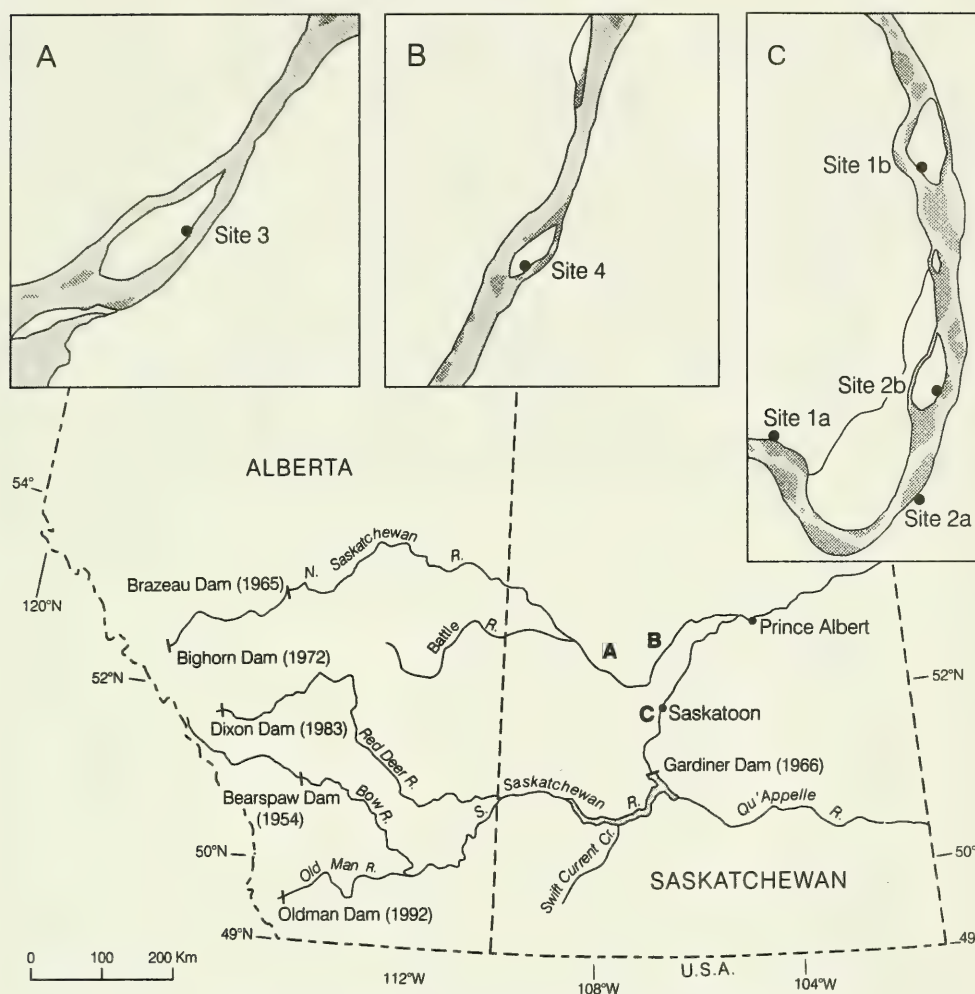


FIGURE 1. General study area and location of the sampling sites.

normal because of drying out of the seedbed. In the first year, drought stress due to poorly developed root systems can further increase mortality, but by the end of the second year the root system may be up to 3 meters long (Read 1958). Other methods of regeneration are asexual propagation through root sprouts and coppicing. Both methods were noted on the North and South Saskatchewan rivers.

Several studies have shown that damming can impact riparian ecosystems because the river flows and controlled water levels no longer match the natural regime (Mahoney et al. 1995; Rood and Mahoney 1990). Similarly, sediments carried by spring flood waters are trapped in reservoirs on regulated rivers; this affects point bar development and channel migration. Thus, Crouch (1979) noted a decline in cottonwoods along the South Platte River in Colorado; similar declines are reported for the

Milk River (Bradley and Smith 1986) and the St. Mary's River (Rood and Heinze-Milne 1989), both located in southern Alberta. High water levels in the spring function to recharge ground water reserves (Hall 1973) which are utilized by the deep roots of the cottonwoods. Without this replenishment there is increased risk of drought-induced mortality of established trees (Reily and Johnson 1981).

In 1968 the Gardiner Dam was closed on the South Saskatchewan River resulting in the formation of Lake Diefenbaker. The purpose of this study is to determine if the damming of the South Saskatchewan River has had an impact on the riparian cottonwood populations at two sites downstream from this dam and compares their age-class structure and population recruitment trends with sites on the nearby, relatively unregulated North Saskatchewan River.

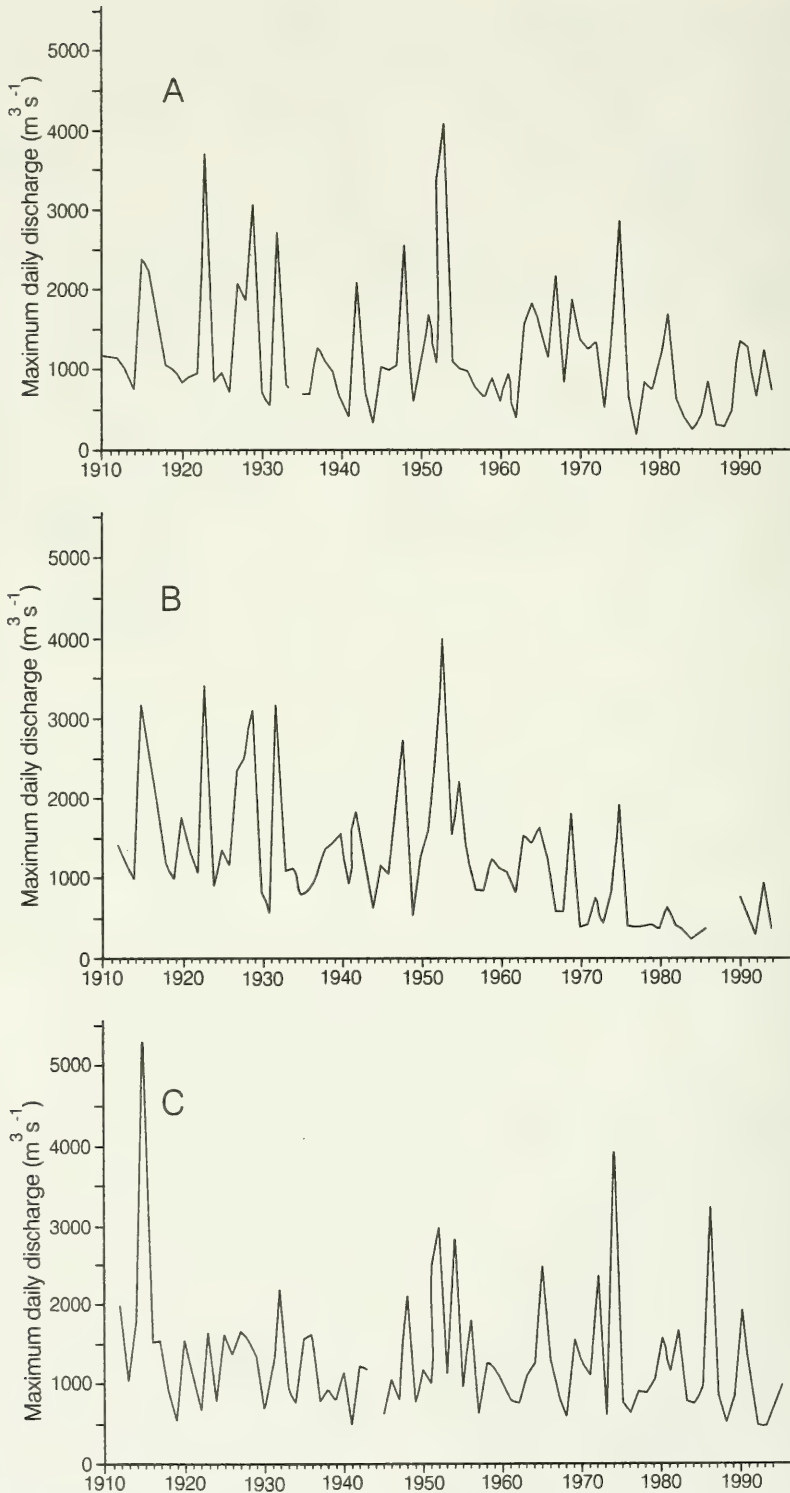


FIGURE 2. Maximum annual discharge. A. South Saskatchewan River at Medicine Hat; B. South Saskatchewan River at Saskatoon; C. North Saskatchewan River at Prince Albert (Source: Environment Canada).

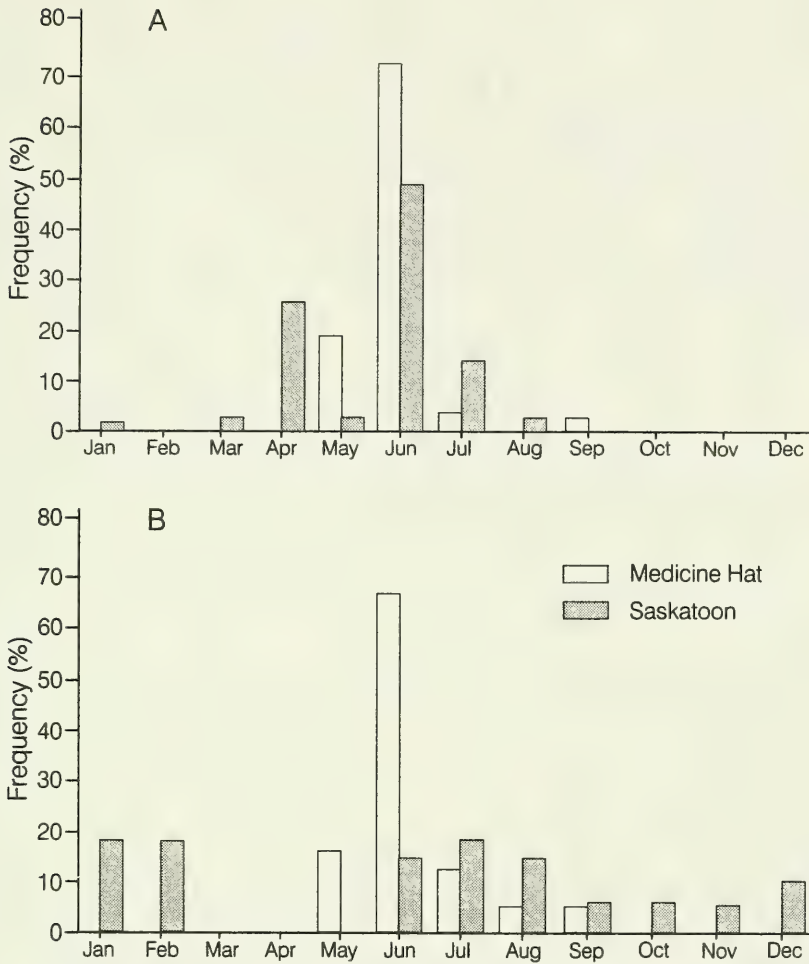


FIGURE 3. Seasonal distribution of maximum annual discharge at Medicine Hat and Saskatoon. A. 1910-1968; B. 1969-1994 (Source: Environment Canada).

Study Area

Together the North and South Saskatchewan rivers and their tributaries drain an area of approximately 336 000 km² and comprise the fourth longest river system in North America. The source of these rivers is the eastern slopes of the Rocky Mountains in Alberta. Both rivers flow eastwards through the foothills region of Alberta and across the prairies eventually entering Hudson Bay by way of the Nelson River. The South Saskatchewan River is created near the Saskatchewan-Alberta border by the merging of the Red Deer, Oldman and Bow rivers, all of which have been regulated (Figure 1). In Alberta the South Saskatchewan River basin has been altered over the past 100 years by the operation of major dams on the main rivers and tributaries. The purpose of these dams is to provide electricity and water for irrigation. The North Saskatchewan

River merges with the South Saskatchewan River approximately 60 km east of Prince Albert, Saskatchewan. Two major dams have been in operation for the past 30 years close to the source of the North Saskatchewan River. These are located some 700 km upstream of the study area and do not appear to have greatly altered local flow regimes. Canada's largest earth filled dam, the Gardiner Dam, was constructed on the South Saskatchewan River over a period of nine years and went into operation in the spring of 1968. The dam is located approximately 100 kilometers upstream of Saskatoon.

The study sites were located on the North and South Saskatchewan rivers near Saskatoon (Figure 1). Here the width of the river valleys vary from 2 to 4 km and exhibit a typical floodplain environment composed of various depositional landforms, such as point bars and islands, and associated mean-

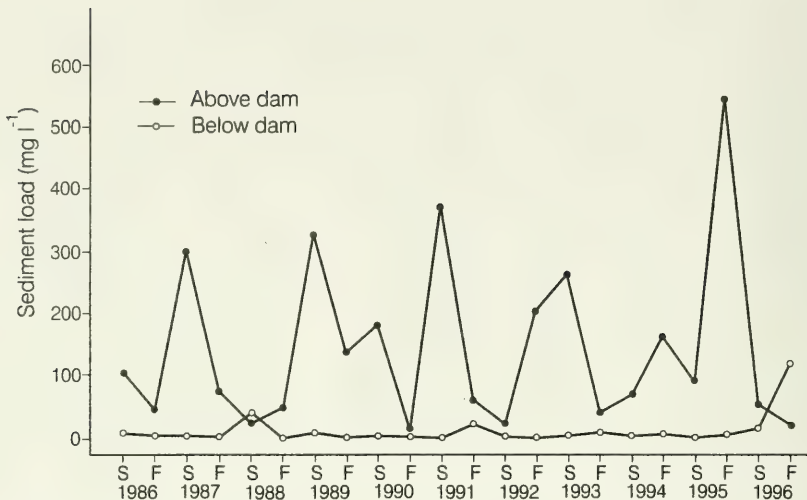


FIGURE 4. Total suspended sediment load in the South Saskatchewan River above and below the Gardiner Dam in spring (S) and fall (F) for the period 1986–1996 (Source: Saskatchewan Environment and Resource Management).

dering river channels. Flow regimes in prairie rivers are characterized by two seasonal high flows. In April and May, snow melt from the surrounding land contributes to the first peak discharge. The second, larger peak usually occurs in June and July and represents a combination of snowmelt in the mountains and spring rainfall. Under natural conditions these events would cause floods of varying magnitude (Stolte and Dumontier 1977*). Following construction of the Gardiner Dam, water levels in Lake Diefenbaker are allowed to rise by 7 to 9 m annually. This has greatly altered river discharge (Figure 2), the time of maximum discharge (Figure 3) and also has reduced sediment loads downstream (Figure 4).

Methods

Two sites were selected on the South Saskatchewan River where stands of cottonwoods were growing both on the banks of the river and on islands. In addition, two island stands were sampled on the North Saskatchewan River. The sites on the South Saskatchewan River were located approximately 5 km south of Saskatoon; those on the North Saskatchewan River were near the Borden Bridge and the Petrofka Bridge which are located 48 km and 60 km from Saskatoon, respectively (Figure 1). At each site a transect was run from the river's edge for a distance of up to 100 meters. Readings were taken with a surveyor's level every 2 meters for the

first 40 m in order to construct a topographic profile of the area in which cottonwood seedlings recently had established. Within this area quadrats 10 m × 10 m in size centered on the transect were set out to sample the density and height of the seedlings which were defined as individuals less than 1 m in height. A nested sampling procedure was used in which five 1 m × 1 m quadrats were located at the corners and centre of the larger quadrats. Within the zone of mature cottonwoods tree density and diameter at 1.3 m above ground was measured in 10 m × 10 quadrats centred on the transect; selected trees were cored for age determinations. Soil pits were dug at points on the transect where seedlings had established and also under established cottonwoods; the texture of the samples was subsequently determined by hand. In addition, plant species representative of this environment were identified at three locations adjacent to each transect. The survey was carried out in the summer of 1996 when river flow was comparatively low.

Results

At the time of the survey exposed sediments stretched for varying distances from the base of the banks to the edge of the channel, so that the zone of seedling establishment was between 4 m and 30 m from the water depending on topographic conditions. Elevations at the end of each transect ranged from about 1 m to 3.5 m above the level of the water, but the zone of seedling establishment was generally about 1 m higher than the water with extreme values of 0.8 m to 1.9 m. Representative bank profiles are presented in Figure 5. The soils in the areas of

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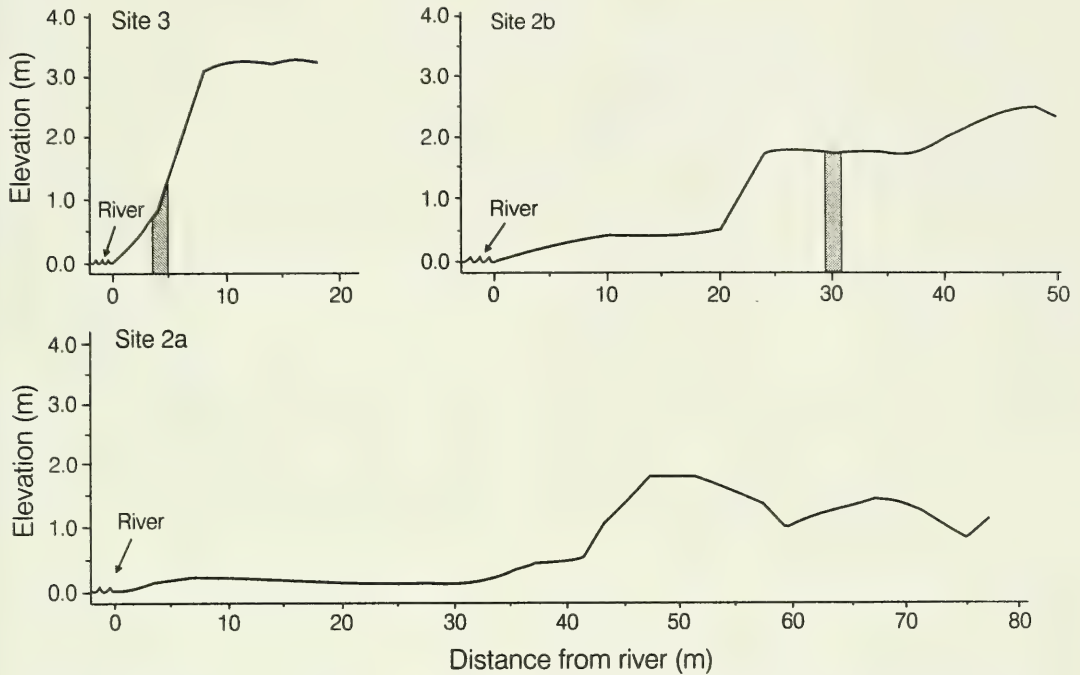


FIGURE 5. Representative bank profiles on the South Saskatchewan River showing the zone of cottonwood seedling establishment (shaded).

seedling establishment were characteristically medium to fine sands with no organic litter layer. A shallow organic horizon was typically present under established cottonwoods with a silty clay layer to a depth of 10 cm. Beneath this the texture changed to fine sand, and became progressively coarser with depth. The most common species found at the sites of seedling establishment were Slender Wheat Grass (*Agropyron trachycaulum*) and Kentucky Blue Grass (*Poa pratensis*). Yellow Willow (*Salix lutea*), Wolf Willow (*Elaeagnus commutata*) and Red Osier Dogwood (*Cornus stolonifera*) were characteristic understory species in the mature cottonwood stands.

A total of 130 mature trees were found at sample sites on the South Saskatchewan River compared to 61 trees on the North Saskatchewan River. The densest stands on the South Saskatchewan River were located at site 1a on a prograding point bar deposit on the west bank of the river. At this site the average density of cottonwoods was 2400 individuals ha^{-1} . Here the trees were growing about 20 m from the river channel at an elevation of approximately 1 m above the water. On a nearby island (site 1b) sampling was conducted on a steep eroding bank. The density of the cottonwoods averaged 1150 individuals ha^{-1} with the edge of the stand 18 m from the river and approximately 4 m above the water. Site 2a comprised a low-lying area characterized by sec-

ondary channels in which local elevation was typically less 1 m above the river rising to the undulating surface of the earlier floodplain on which mature cottonwoods were established; tree density in this stand averaged 1400 individuals ha^{-1} . Site 2b was on an adjacent island in the main channel. Elevations at this site were less than 1 m above the river at a distance of 20 m from the channel, but then rose steeply to an older floodplain about 2.5 m above the water. Mature cottonwoods grew up to the crest of the slope; the average density of this stand was 700 individuals ha^{-1} .

The Borden Bridge site (site 3) on the North Saskatchewan River was located towards the downstream end of an island. The bank rose steeply from the river's edge to a height of approximately 3 m before sloping gently downwards away from the river. Mature cottonwoods were present at a distance 15 m from the river. Average density of this stand was 165 individuals ha^{-1} . At Petrofka Bridge (site 4) a small beach extended some 15 m from the island at which point the bank rose steeply to a height of approximately 3.5 m. Established cottonwoods were found at a distance of 22 m from the river with a stand density of approximately 100 individuals ha^{-1} .

Several of the trees were cored, although age determinations were difficult because the annual rings were indistinct and many of the older trees

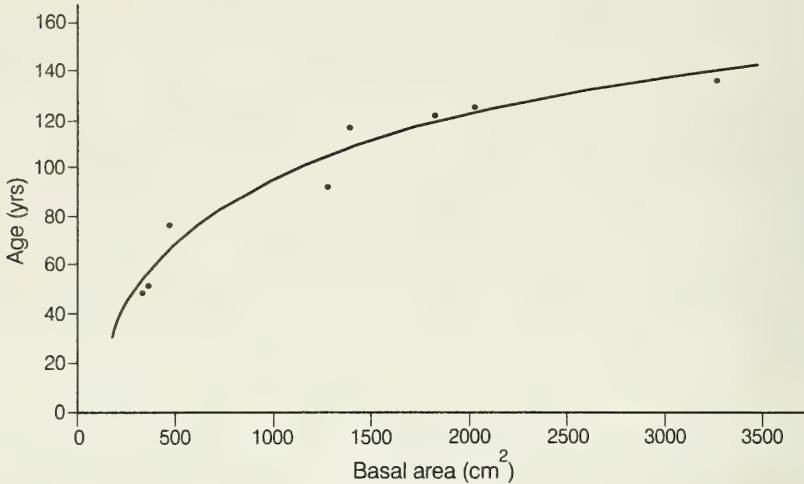


FIGURE 6. Age determination curve for riparian cottonwoods on the the North and South Saskatchewan rivers.

suffered from heart rot. Consequently, only eight trees could be used to establish the growth curve presented in Figure 6. The average age of the cottonwoods on the South Saskatchewan River was 50 years compared to 61 years for those on the North Saskatchewan River. Composite age-class distributions for these two populations indicate that 35% of the cottonwoods at sites on the South Saskatchewan River have established since construction of the Gardiner Dam compared to 54% on the North Saskatchewan River (Figure 7). Age-class distributions were extremely variable between sites. Thus, post-dam recruitment at sites on the South Saskatchewan River was highest at site 2a and accounted for 43% of the established population, compared to 42% at site 1a, 17% at site 2b and only 4% at site 1b. On the North Saskatchewan River 69% of the established cottonwoods were less than 27 years old, compared to only 7% at site 4b. The possibility that population recruitment on the South Saskatchewan River has been affected by construction of the Gardiner Dam was analyzed using the Kruskal-Wallis test. The results indicated that there was no significant difference between the two established populations.

Cottonwood seedlings were present at four of the sample sites where a total of 337 seedlings were recorded ranging in height from 5 to 74 cm (Figure 8). Because cottonwood seedlings grow rapidly, it was assumed that all of the seedlings had established in the previous two years. Mean seedling densities ranged from 5 seedlings m⁻² at site 3 to 29 seedlings m⁻² at site 4; none were present at sites 1b and 2a. At site 1a the seedlings had established on the point-bar deposits on the inside bend of a meander, and at

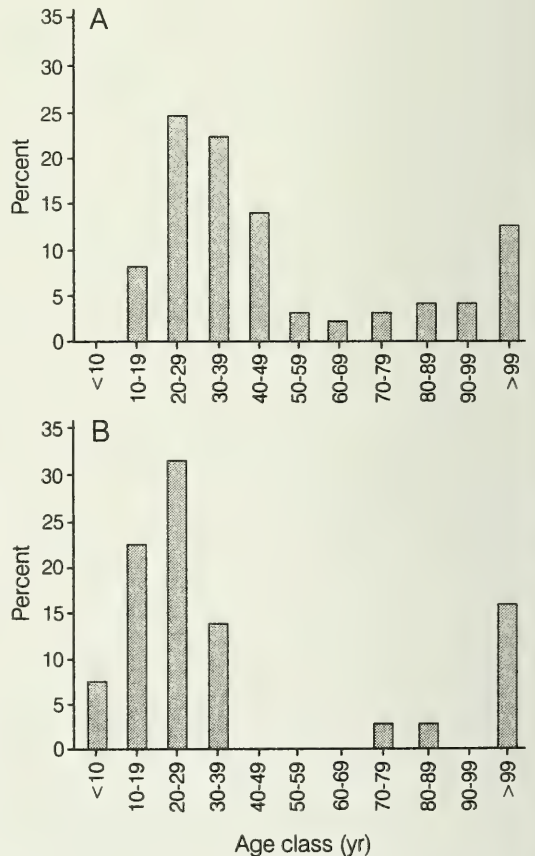


FIGURE 7. Age-class distributions of riparian cottonwoods: A. South Saskatchewan River B. North Saskatchewan River.

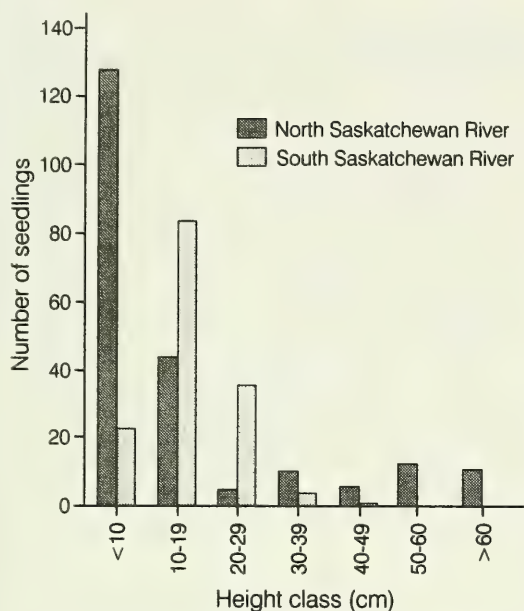


FIGURE 8. Height-class distributions for cottonwood seedlings on the North and South Saskatchewan rivers.

the time of the survey were at an elevation of 1.2 m above the water. Numerous sand bars had formed adjacent to the island at site 2b, and seedlings were restricted to the east bank of the island away from the main channel. The mature cottonwoods on the other side of the island were the probable seed source for these young seedlings. Here the zone of seedling establishment was some 30 m from the river's edge at an elevation of 2.0 m. The seedlings at site 3 had established in a band 0.8 to 1.0 m above the water on a fairly steep bank away from the main channel; young saplings were present above this becoming progressively older with distance from the river with stands averaging 20 years in age some 60 m away. Evidence of extensive Beaver (*Castor canadensis*) activity was noted on the younger trees. At site 4 seedlings had established about 0.8 m above the water and continued up the bank to about 1.4 m forming a narrow band about 20 m from the water. The zone of seedling establishment was about 20 m from the older trees which were found on the higher parts of the island about 40 m from the river.

Discussion

Changes in flood frequency and flood magnitude, and seasonal alterations in peak discharge patterns have a noticeable impact on the riparian species which inhabit floodplain environments. Cottonwoods are especially sensitive to altered hydrological regimes. Seedling establishment coincides with natural flood events at which time mature

trees release large numbers of short-lived seeds. Successful establishment is restricted to critical zones on alluvial point bars that are high enough to resist scouring during peak flow periods and low enough to avoid desiccation as the water level subsides later in the growing season (Segelquist et al. 1993). Even under natural conditions seedling mortality is high and typically results in localized patches of even-aged trees.

The Gardiner Dam on the South Saskatchewan River has been closed for about 30 years resulting in significant changes in the discharge characteristics downstream, so that flow regimes are quite different from those on the nearby North Saskatchewan River. Discharge flows will continue to change because of increased water use. In 1983, the rate-of-rise restriction in the reservoir was lifted allowing managers more latitude in dampening discharge peaks. Operating standards for the reservoir strongly favor deviation from normal flows – elimination of peaks and lows – as this optimizes power generation and minimizes disruptions to downstream users including ferry and irrigation operations. As well, erosion is reduced in the floodplain upstream of Saskatoon, an area which experiences some of the highest rates of erosion in the province.

Maximum flow through the power-generating turbines at the Gardiner Dam is $375\text{--}400\text{ m}^3\text{ s}^{-1}$. This is equivalent to a rise in stage of 0.6 meters above low flow ($45\text{ m}^3\text{ s}^{-1}$) at Saskatoon (Figure 9). Water level is one of many factors which affects the zone of seedling establishment, which in this study ranged from 0.8 m–1.9 m above low water. This suggests that the optimum discharge for power generation is not suitable for cottonwood regeneration. Consequently, since the dam was completed the only opportunity for cottonwood establishment occurs during spill events in which surplus water is released. Over the past 29 years there have been five such spills, with the most recent occurring in 1995 peaking at $1200\text{ m}^3\text{ s}^{-1}$. This translates to a stage increase of 1.3 m above low water at Saskatoon.

Although apparent differences in the age-class distributions of cottonwoods on these two rivers were not statistically significant due to the small number of sample sites, it is interesting to note the absence of young established trees and fewer seedlings in the South Saskatchewan River population. High flows still occur on the South Saskatchewan River, but the timing and magnitude of these events is quite different from the pre-dam period with considerably more water being released in the non-growing season. Changes in sediment transport are equally important. The sediment load in the South Saskatchewan River is greatly reduced downstream from the Gardiner Dam and this will ultimately affect floodplain development with less meandering (Williams and Wolman 1984) and limit-

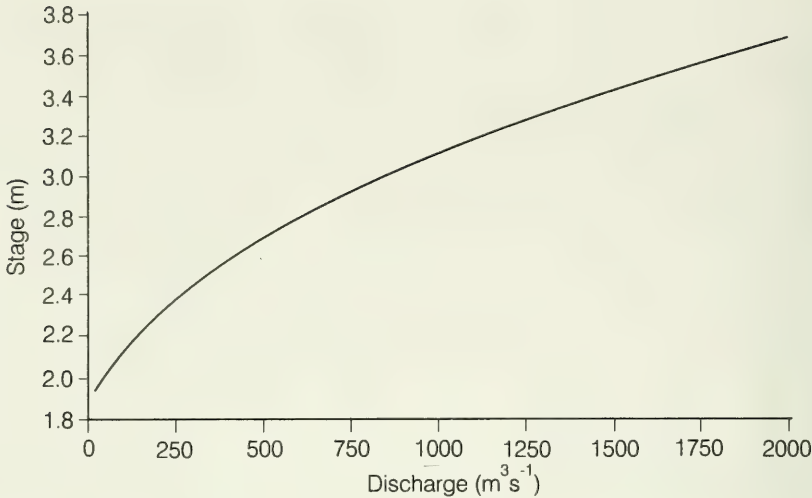


FIGURE 9. Rating curve for the South Saskatchewan River at Saskatoon.

ed deposition of substrates suitable for cottonwood establishment (Rood and Heinze-Milne 1989). Pointbars prograde as sediment is deposited in subsequent floods and over time the frequency of submergence gradually decreases. Although cottonwood seedlings can tolerate flooding for periods as long as 30 days (Hosner 1957), they may be removed by scouring. Thus, lower elevations may not be suitable for long term success. This could ultimately lead to a significant change in the structure of the cottonwood population. Such changes have been noted in the riparian zone along the North Platte River in Wyoming. Here the area occupied by cottonwood stands with less than 30% canopy closure decreased in the period 1937-1990 following water impoundment, while stands with canopy closure exceeding 70% decreased. Thus the cottonwood population changed from young denser stands to older, more open stands (Miller et al. 1995).

Cottonwoods are also susceptible to drought induced mortality, and was especially prevalent during the droughts of the 1930s (Albertson and Weaver 1945). Seedlings and saplings are especially sensitive because of their shallower roots, but trees older than 30 years were also more likely to die, often showing signs of early leaf senescence and leaf abscission and death of branches prior to the death of the individual trees. The possibility of drought stress is increased when summer discharge is reduced on dammed rivers. An abrupt reduction in water levels is considered the most stressful, since natural variations in flow regimes afford poplars with a period of hardening which increases drought tolerance (Rood and Mahoney 1990). Changes in tree growth rates have been attributed to altered flow patterns and is especially apparent in semi-arid environments where the beneficial effect of inundation in

years of high annual evapotranspiration is lost (Rood et al. 1995). Ultimately this may cause a change in the composition of riparian woodlands. For example, growth of American Elm (*Ulmus americana*) and Box Elder (*Acer negundo*) have decreased noticeably along the Missouri River since damming (Reilly and Johnson 1982). Similarly, litter production is reduced although decomposition rates are higher in flooded sites compared to non-flooded sites (Molles et al. 1995). Changes in these processes brought about by altered river flow could therefore have a long-term influence on soil nutrient reserves and be an additional factor in community change. A review of the vegetation surveys in the Saskatoon area conducted by Hall (1973) and Lineman (1993*) did not provide conclusive evidence of substantial changes to floodplain vegetation during the 20-year period. In addition to altered hydrological regimes, other factors, such as clearing of riparian woodland for irrigated agriculture and allowing livestock access to river banks, can also threaten cottonwood stands through grazing, trampling of seedlings and spread of exotics. This has certainly occurred along the South Saskatchewan River Lineman (1993*).

The cottonwood life cycle is adapted to an environment of periodic flooding. Water level control has greatly altered the flow characteristics of the South Saskatchewan River following the construction of the Gardiner Dam in 1968 and the creation of Lake Diefenbaker. Spring and early summer floods occur infrequently on the South Saskatchewan River below the Gardiner Dam and the establishment of cottonwoods may be threatened by changes to the natural river regime. Preliminary evidence suggests the progressive aging of the remnant cottonwood populations. Thus there is a possibility that significant changes in the riparian vegetation of the South

Saskatchewan River valley may arise unless periodic flooding and other management strategies are adopted to reduce mortality of the cottonwoods and limit the invasion of exotic species.

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Over-Ocean Flocking by Dunlins, *Calidris alpina*, and the Effect of Raptor Predation at Boundary Bay, British Columbia

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Dekker, Dick. 1998. Over-ocean flocking by Dunlins, *Calidris alpina*, and the effect of raptor predation at Boundary Bay, British Columbia. *Canadian Field-Naturalist* 112(4): 694–697.

Flocks of Dunlins (*Calidris alpina*) often exceeding 10 000 birds, wintering at Boundary Bay, British Columbia, remained airborne over the ocean for 2–4 hours when their intertidal feeding grounds were inundated. I postulate that this behaviour is an adaptation to avoid surprise attacks by raptors over the saltmarsh where open roosting habitat is absent. Peregrine Falcons (*Falco peregrinus*) attacked Dunlins 302 times with 28 captures, a success rate of 9.3%. Surprise hunts over the saltmarsh had a success rate of 33.0% in 15 hunts, significantly higher ($P < 0.05$) than the 8.0% in 287 hunts over the open mudflats. All 29 hunts by Merlins (*Falco columbarius*) began as surprise attacks although all five kills were made after long pursuits.

Key Words: Dunlin, *Calidris alpina*, over-ocean flocking, Peregrine Falcon, *Falco peregrinus*, predation, British Columbia.

Shorebirds wintering or staging on coastal estuaries mass together during high tide on traditional roosting sites that remain above water (Morrison 1977; Hicklin 1987; Mawhinney et al. 1993). In Washington State, wintering Dunlins (*Calidris alpina*) fly to wave-swept beaches that can be as far as 15 km from the estuaries (Buchanan 1996). In Holland, Knots (*Calidris canutus*) roost on open mudbanks 7.5 km away from their feeding grounds (Piersma 1994). In California, wintering Dunlins and other sandpipers collect on shoreline pastures when the adjacent lagoon becomes inundated (Page and Whitacre 1975). Dunlins wintering in coastal British Columbia roost on inland fields (Butler 1994).

Open-country birds flock together as a response to predation. Individuals in large flocks have a lower chance of being killed by an attacking raptor, and they spend significantly less time in surveillance and more time feeding than do individuals in small flocks or lone birds (Powell 1974; Lima 1987). Dense flocks might also discourage predators from entering for fear of damaging themselves (Tinbergen 1951). At the approach of predators, flocks of shorebirds engage in tightly synchronized flight manoeuvres (Buchanan 1996). Falcons selectively hunt lone and juvenile shorebirds (Dekker 1980; Kus et al. 1984; Bijlsma 1990; Warnock 1994). This paper reports on the roosting behaviour of Dunlins and their interaction with predators at Boundary Bay in southwestern British Columbia.

Study Area and Methods

Boundary Bay is part of the Fraser River delta (49°05'N, 123°00'W) in southwestern British Columbia. The bay is 16 km across and the intertidal zone is roughly 4 km wide at the lowest ebb. During January, daytime high tides reach over 5 m above lowest normal tides (Pt. Atkinson chart) and inun-

date all mudflat habitat including most of the narrow strip of saltmarsh. The bay is contained by a low dike and the adjacent delta is mainly farmland. Rich in marine foods, Boundary Bay is a major migration stop-over for shorebirds and a wintering ground for 25 000–35 000 Dunlins (Butler 1994; Butler and Kaiser 1995). Raptors are common. For a more detailed description of the Fraser River delta and its avian inventory see Butler and Campbell (1987).

During January 1994–1998, I spent 54 days, from first light to dusk, in the study area. Especially during windy and rainy weather, I watched from a parked car. At other times I walked on the dike. I roughly estimated Dunlin numbers by counting them on small sections of shore and extrapolating the totals during outgoing tides when the birds spread out over the mudflats. I frequently scanned the area through binoculars to discover alarm behaviour of Dunlins and to spot predators. Flying falcons were watched until they flew out of sight. Perched falcons were monitored through binoculars or a telescope in the hope of seeing them attack prey. The term “hunt” means one completed attempt at capturing a Dunlin of which the outcome was known. This conforms with the definition used by other researchers who presented large data sets on raptors hunting shorebirds (Page and Whitacre 1975; Dekker 1980, 1988; Cresswell 1996).

Results

High-Tide Behaviour of Dunlins

Each January I estimated total Dunlin numbers in Boundary Bay at >30 000. When the flood tide inundated the mudflats, the Dunlins assembled along the edge of the saltmarsh. As the tide crested, many birds stood up to their bellies in water before they finally flew away. Some flocks departed inland, particularly after heavy rain when fields and meadows

became water-logged. However, the majority of the Dunlins flew out over the ocean, where they coursed back and forth. The flock drifted in a loose cloud on the wind or coalesced into a dense, undulating stream low over the waves. The Dunlins frequently split up and rejoined again later or merged with other flocks.

I first noted this flight behaviour in the late afternoon of 23 January 1994, when I watched the flocks for 1.5 h and did not see them return to land. During subsequent observations, the above described behaviour proved to be routine. Depending on the timing of the tides, I often saw the entire high-tide flocking intermezzo including the birds' return 2–4 hours later. The time span appeared to vary with the height of the tide and the extent to which the saltmarsh had been inundated.

While the flocks were airborne over the ocean, their flight pattern was influenced by weather conditions. With light winds, the birds cruised about slowly with fluttering wings in loose aggregations that looked from a distance like veils of fog or smoke. During rain, or when strong winds were blowing, the flocks were generally much smaller and flew very low over the waves, making slow progress and often dipping out of sight. On some stormy days no birds could be seen with the unaided eye. It is possible that they had departed for some distant roosting site. However, scanning the ocean through binoculars, I usually picked up one or more flocks estimated to be >2 km offshore.

When the tide began to ebb, flocks of Dunlins returned over the water or flew upwind along the shore. Landing tentatively on the first points to emerge, the birds soon spread out into the shallows to feed. In the meantime, smaller flocks returned from inland roosting sites.

Predator Interaction with Dunlins

The number of predators seen during this study included eleven species of diurnal raptors and two owls. However, only five species of birds of prey and one gull attacked and chased Dunlins. The most common raptor to hunt them was the Northern Harrier (*Circus cyaneus*). I did not estimate its local population but recorded numerous sightings each day. Harriers frequently approached Dunlins in a low sprint intended to take a prey by surprise. I saw three distant captures, with the harrier immediately descending into vegetation. Once the Dunlins were airborne, harriers did not pursue them for more than a few seconds, and the Dunlins descended again very soon, often returning to the same place.

Each winter there were at least five or six different Peregrine Falcons (*Falco peregrinus*), recognizable by differences in size and plumage, foraging over the bay. I saw one or more each day and recorded a total of 302 hunts aimed at Dunlins including 28 captures. Hunting peregrines caused violent panic responses

among the Dunlins, which mounted high into the sky and formed dense globular flocks. After one or more attacks, the flocks abandoned the immediate area and descended >1.5 km away.

Dunlins reacted similarly to hunting Merlins (*Falco columbarius*). Although there probably were more than one Merlin in the area, I did not see them each day. I saw 29 Merlin attacks on Dunlins, resulting in five kills. Merlins as well as peregrines employed a wide variety of hunting methods, including low surprise approaches, multiple stoops at flying flocks and long pursuits of single Dunlins.

A locally abundant, potential predator of Dunlins was the Glaucous-winged Gull (*Larus glaucescens*). It had little chance of catching a Dunlin on open mudflats, but it was opportunistic. Once I saw a swimming gull, head held low, approach and suddenly lunge at Dunlins feeding along the edge of the saltmarsh. After watching half a dozen tries, I just missed the moment of capture, but I saw this gull swallow a Dunlin, head first, which was still alive and vigorously flapping its wings. This incident happened in January 1998 during a spell of extreme cold when the Dunlins were probably hungry and less alert to danger.

Bald Eagles (*Haliaeetus leucocephalus*) were numerous (100–200) and attempted to klepto-parasitize peregrines and Merlins carrying prey. I saw one eagle force a peregrine to drop its just-caught Dunlin. Eagles, as well as gulls and harriers also joined chases in progress, attempting to pick up Dunlins that were struck down by the falcon or took cover in water or vegetation. Eagles succeeded in three of these pursuits. The loss of prey forced the falcons to hunt again. Another successful klepto-parasite was a Prairie Falcon (*Falco mexicanus*) which wintered in the area in 1997. It twice attempted to rob a peregrine of a just-caught Dunlin, once succeeding.

Peregrines and Merlins hunted throughout the day, even at low tide when they were far from shore and easily escaped detection. They also attacked the flocks that were cruising over the ocean at high tide. Although I did not attempt to correlate sightings with time of day or the tides, it appears that I saw falcons most often just before or after high tide when they hunted not far from shore. As the tide reached its peak and the Dunlins were massing together near shore, they appeared to be very nervous and were frequently harassed by Harriers. The approach of Merlins and peregrines, streaking at high speed over the vegetation of the saltmarsh, would immediately result in the flock's departure and trigger the high-tide flocking intermezzo.

The number of times peregrines were seen to make surprise attacks over the saltmarsh was small ($n = 15$) because the Dunlins spent little time there. Five ended in capture, a success rate of 33.3%, significantly high-

er ($G = 4.83$ $P < 0.05$) than the 8.0% in 287 hunts over the open mudflats and the ocean. I observed several surprise attacks by Merlins, low over the saltmarsh, but the outcome remained uncertain because the Merlin became hidden from view among flushing Dunlins. I spotted two Merlins carrying prey over the saltmarsh, but I had missed the initial phase of the hunts. All 29 Merlin hunts which I observed from their beginning to the end began as an attempt to take a Dunlin by surprise, even over open mudflat habitat. All failed. Subsequently, these Merlins changed their tactics and attacked flying flocks, attempting to isolate an individual, far out over the mudflats. All five captures were the result of long pursuits. For a more detailed account of peregrine and Merlin foraging habits see Dekker (*in press*).

Discussion

The 9.3% hunting success of peregrines in this study is nearly equivalent to other studies (Table 1). The 17.2% success rate of Merlins, although the sample is small, is higher than rates reported elsewhere (Table 1).

The most common hunting strategy used by peregrines and Merlins was surprise, which was also the main method of falcons hunting shorebirds elsewhere (Page and Whitacre 1975; Dekker 1980, 1988; Cresswell 1996). Nevertheless, in this study most captures by peregrines (20 of 28) resulted from attacks on flying flocks and long pursuit of single Dunlins. All five kills by Merlins were the result of long pursuits, after attempts at surprise failed. As Dunlins avoided the shore, the falcons were forced to hunt over the open flats where surprise was more difficult to achieve. In this study, I observed many different individual peregrines and their hunting styles varied. Some adults hunted exclusively by surprise, whereas the immatures varied their methods and often pursued and repeatedly swooped at a sin-

gle Dunlin until it was either caught or escaped into cover.

Dunlins, like many other small shorebirds, do not like to sit in vegetation because it blocks their view and predators are quick to take advantage of cover to maximize the element of surprise (Dekker 1980, 1988). Therefore, I postulate that high-tide flocking, as observed in this study, is an anti-predator strategy.

Dunlins at Boundary Bay had to resort to high-tide flocking because they could not locate suitable, bare ground for roosting after all of the intertidal zone had been inundated by the high tides. I hypothesize that these Dunlins, instead of remaining airborne over the ocean, would have roosted on open sites if these had been available. They do so in adjacent Washington State (Buchanan 1996). Interestingly, at Tsawwassen, 5 km northwest of Boundary Bay, several thousand Dunlins mass together at high tide on the gravel tip of the breakwater jetties of the ferry terminal (Rick Swanston, personal communication). In addition, as mentioned, a portion of the Dunlins fly inland. Their number can be substantial. Butler (1994) counted a January maximum of 13 400 on fields in the Fraser delta. Roosting on fields, as well as on ferry jetties, must be seen as a relatively recent adaptation, as such opportunities were absent prior to European settlement of the area, about a century ago, when the entire delta was likely covered with dense vegetation. It will be interesting to see whether inland roosting increases in future.

The metabolic cost to shorebirds of flights to and from distant roosting sites is considerable (Piersma 1994). The expenditure of energy during the high-tide flocking phenomenon reported in this study is probably only possible if the birds have access to an abundance of food. This appears to be the case; Boundary Bay is exceptionally rich in marine organisms (Butler 1994). It is interesting to observe Dunlin behaviour when and where these food resources are less accessible. I saw no high-tide flocking during an extreme cold spell in January 1998, when most of the intertidal zone at Boundary Bay was covered with ice. Small flocks of Dunlins that remained in the area stood on the ice far from shore. Other small flocks spent the high-tide period searching for food in the saltmarsh. After the tide dropped, these Dunlins moved back onto the mudflat, feeding ravenously. Astonishingly, they showed minimal reaction to hunting peregrines and Merlins. Instead of taking to the air in defensive formations, only those Dunlins directly in line with the approaching falcon got out of the way, to quickly land again. I hypothesize that these Dunlins had no energy to waste. The need to eat and the need to avoid predation is a trade-off. After the cold spell, Dunlins quickly returned to former numbers and high-tide flocking resumed. I saw no high-tide flocking during two days in April 1998 when the daytime

TABLE 1. Success rates of Peregrine Falcons and Merlins hunting small shorebirds.

Number of hunts	Captures	% Success	Source
Peregrines			
302	28	9.3	This study
233	20	8.6	Cresswell 1996
569	50	8.8	Dekker 1988
Merlins			
29	5	17.2	This study
182	21	11.5	Cresswell 1996
343	44*	12.8	Page and Whitacre 1975
223	28	12.6	Dekker 1988

*Includes a small but unspecified number of passerines.

In all these studies a hunt was defined as a completed attempt at capturing a prey of which the outcome was known.

high tides remained about 1 m below January levels. Then, the Dunlins and other sandpipers stayed on the flats away from shore all day.

The significance of the phenomenon reported in this study, that many Dunlins fly out over the ocean during the entire high-tide interval in January when all of the intertidal zone is inundated by peak tides, has to my knowledge not been recognized before. High-tide flying of shorebirds has also been observed at several locations along the Atlantic Coast of Canada but it has not been singled out for publication (Tony Erskine, personal communication).

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Notes

Diurnal and Nocturnal Behavior of Black Bears, *Ursus americanus*, on Bear Trails

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Reimchen, T. E. 1998. Diurnal and nocturnal behavior of Black Bears, *Ursus americanus*, on bear trails. *Canadian Field-Naturalist* 112(4): 698–699.

Well-used and possibly ancient bear trails occur in different regions of the home range of bears (*Ursus*) and are suspected of functioning in intraspecific communication. I monitored Black Bears (*U. americanus*) in a riparian habitat of an old growth forest on the Queen Charlotte Islands during daylight and also during darkness with the use of light-enhancing night-viewing goggles. During daylight, bears regularly moved off the trails on first visual detection of my presence (>20 m). However, during darkness, bears maintained high fidelity to these trails even during my close approaches (1 m), suggesting these trails act as nocturnal sensory corridors.

Key Words. American Black Bear, *Ursus americanus*, nocturnal behaviour, bear-human interactions, bear trails, scent marking, Queen Charlotte Islands.

Bear (*Ursus* spp.) trails with individual foot impressions in the substrate occur in a diversity of habitats and represent ancient or at least long-term evidence of activity (Murie 1981; summary in LeFranc et al. 1987*). In habitats with dense ground vegetation or obstructions, these old trails may represent natural corridors of least resistance. However, in open forests and meadows the trails could provide visual and tactile information for intraspecific signalling (Burst and Pelton 1979; Hamilton and Archibald 1986*). Scent-marking occurs along these trails resulting in a potential olfactory map of the habitat (Nikolaenko *in press*).

Most behavioural observations of Black Bear (*U. americanus*) and Brown Bear (*U. arctos*) have been made during daylight (Herrero 1985; Powell et al. 1997) and, accordingly, the ecological role of trails and scent marking has only been addressed in context of daylight activity. Bears can also be active during darkness (Frame 1974; Matchutson et al. *in press*; Olson et al. *in press*). Recent development of high resolution night-viewing glasses now provides an opportunity to study directly nocturnal bear activity (Reimchen 1994*) such as their foraging behavior (Reimchen 1988). As part of this investigation, I also recorded differences in the behaviour and movement of bears during daylight and darkness which I describe in this note.

The observations were made at Bag Harbour in the southern region of Haida Gwaii (formerly Queen

Charlotte Islands), some 80 km off the coast of central British Columbia. The old growth forests beside the estuary and stream have well-worn bear trails in moss substrata and include distinct foot depressions. These trails extend from the stream several hundred metres into the forest. Trails occur adjacent to areas of high salmon spawning density and as "short-cuts" through the forest between adjacent bays of the estuary. During my daily surveys for bear foraging activity in the watershed (in October 1992 and October 1993), I always attempted to move quietly with minimum disturbance. When encountering a bear, I recorded its general responses and visually estimated its distance from me. During darkness, I used head-mounted full-face goggles (Model AN/PVF5, USA, light amplification 110 000×, resolution 270 000 pixels); these provided average viewing conditions approximately equivalent to mid-day light levels during overcast conditions. Bears congregated in prime foraging areas during darkness and there were a maximum of six during these congregations (Reimchen 1994*). All bears were adult size and I could not reliably differentiate sex or age of individuals.

Results show consistent differences in bear movement between daylight and darkness. During daylight, bears retreated farther into the forest when encountering other bears or myself. Bears detected me at distances up to 100 m if I was moving but at distances of 10–20 m when I was stationary. When I was behind an obstruction and not visible to the bear, the directed sniffing in my direction indicated detection. They did not retreat in these situations until

*See Documents Cited section

they detected me visually. On five occasions when I was moving through the forest on bear trails away from the stream, I encountered solitary adult bears moving along the trails towards the stream. When I was first detected visually (ca 10-25 m), bears immediately moved off the trail in a broad arc just outside of visual contact with me and rejoined the trail and continued to the stream. Extending from 38 days of observations on the bears (1992, 1993), it was evident that visual cues were a dominant factor in agonistic responses among bears during daylight as evasive responses of bears occurred on initial visual detection of other bears rather than on auditory or olfactory detection.

During darkness, responses of bears to me were substantially different than those during daylight. On the intertidal regions of the estuary, at least four different bear would pass by me at close distance (1-6 m) if I was positioned near any of the routes that bears regularly used in transit from the forest to the tideline. Bears were aware of my presence as they sniffed in my direction when passing me. However, they did not appear to detect me visually because when I motioned silently with my arms, the bears did not respond; comparable action during daylight evoked an immediate evasive response of the bear. On two occasions during darkness, when I was moving through the forest on a bear trail, I encountered an adult bear walking in my direction on the trail. The bear did not exhibit obvious awareness of my presence until it was within 20 m when it began extensive sniffing in my direction. It continued the approach to within 5 m and remained at this distance and appeared unwilling to move around me. Only when I moved several paces off the trail did the bear cautiously and slowly move past me but even during the point of closest approach, it maintained fidelity to the trail. The reluctance of the bear to move off the trail during darkness was puzzling as they readily moved off the trail during daylight. There were no physical barriers or obstructions on either side of where I stood which would have restricted its movement.

The most plausible interpretation for the close proximity with which bears would pass me during darkness without leaving the established trails is that movement off the trail would leave the bear with inadequate tactile or olfactory input for movement on novel terrain. If so, I suggest that these established trails have an important ecological role facilitating bi-directional movement in darkness. When these trails are used as communal corridors, then they may also serve to impart sensory cues of home range and individual identification (Burst and Pelton

1982; Herrero 1985; Hamilton and Archibald 1986*; Nikolaenko *in press*).

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Arctic Fox, *Alopex lagopus*, Predation on Lesser Snow Geese, *Chen caerulescens*, and their Eggs

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Samelius, Gustaf, and Marc Lee. 1998. Arctic Fox, *Alopex lagopus*, predation on Lesser Snow Geese, *Chen caerulescens*, and their eggs. *Canadian Field-Naturalist* 112(4): 700–701.

At Egg River Colony on Banks Island, we observed previously undocumented predation by Arctic Fox on Lesser Snow Geese and their eggs. On separate occasions, we observed (1) an Arctic Fox attack and kill a nesting Lesser Snow Goose and (2) an Arctic Fox take eggs from Lesser Snow Geese as birds were pushed off nests by a charging Muskox. Despite several studies on interactions between Arctic Foxes and nesting geese, there is, to our knowledge, no documented observation of an Arctic Fox killing a nesting goose. Thus, we suggest such mortality to be relatively uncommon and most goose parts in Arctic Fox diets to be the result from scavenging of goose carcasses, or killing of goslings and molting adults during the brood-rearing season. The observation of the fox taking eggs from geese as they were pushed off nests by a Muskox illustrates the opportunistic nature of Arctic Foxes not only in choice of diets, but also in how foods are acquired.

Key Words: Arctic Fox, *Alopex lagopus*, Lesser Snow Goose, *Chen caerulescens*, Muskox, *Ovibos moschatus*, foraging behaviour, opportunistic behaviour, predation, disturbance, scavenging, Banks Island.

Arctic Foxes (*Alopex lagopus*) are opportunistic predators and scavengers that rely heavily on small mammals throughout most of their range (Chesemore 1968; Macpherson 1969; Speller 1972; Kennedy 1980; Garrott and Eberhardt 1987; Fay and Stephenson 1989). However, other prey items, such as birds and their eggs, and carrion from sea mammals and marine invertebrates, can be important in years and areas of low lemming numbers (Chesemore 1968; Garrott and Eberhardt 1987; Fay and Stephenson 1989; Stickney 1991; Prestrud 1992; Hersteinsson and MacDonald 1996). In fact, Prestrud (1992) suggested that ability to learn new hunting skills and exploit local variation of foods are crucial factors for survival of Arctic Foxes.

In some areas, geese constitute an important part of Arctic Fox diets (Stickney 1991; Prestrud 1992; Hersteinsson and MacDonald 1996; Bantle and Alisauskas 1998). However, despite several studies on interactions between Arctic Foxes and nesting geese (e.g., Speller 1972; Stickney 1991; Syroechkovskiy et al. 1991; Prestrud 1992), there are no reported observations of Arctic Foxes killing nesting geese. To our knowledge, Speller's (1969) report of an Arctic Fox killing a molting flightless goose is the only documentation of an Arctic Foxes killing an adult goose.

Observations reported here were made at Egg River Colony on Banks Island (72°25'N, 124°32'W) and was part of a study on productivity of Lesser Snow Geese (*Chen caerulescens*) on Banks Island, Northwest Territories. Egg River Colony is the largest Lesser Snow Goose colony in the Pacific Flyway (Kerbes 1994) and consisted of about 400 000 nesting Lesser Snow Geese in 1996 (Samelius and Alisauskas 1997*).

On 26 June 1996, GS observed an Arctic Fox attack and kill an incubating Lesser Snow Goose. This observation was made in late incubation and occurred about 05:20. It was observed with a spotting scope (15–45×) from a large hill at a distance of approximately 0.5 km. The bird that was killed was a female whose mate was temporarily absent (but see below). As the female was attacked, she came out about 1–2 m from her nest to defend against the fox and was killed by the fox jumping on to her, holding her, and biting her to death. The fox fed on the bird for about 1–2 minutes, then took an egg from the nest and left to cache the egg. When the fox got back from caching the egg, a Glaucous Gull (*Larus hyperboreus*) had landed by the nest and removed two eggs out of the nest bowl. The fox fed on one of these eggs for about 2 minutes, then took another egg out of the nest and left with the egg in its mouth. The male goose returned to the nest about 10 minutes after the fox had left. By then, the gull was feeding on the carcass of the dead female.

On 28 June 1996, ML observed an Arctic Fox take eggs from two different Lesser Snow Goose nests as parents were pushed off nests by a charging Muskox (*Ovibos moschatus*). This occurred on separate occasions and each time each pair lost one egg. This observation was made in late incubation and occurred between about 02:00 and 03:00. It was observed with a spotting scope (15–45×) from a large hill at a distance of approximately 0.5–1.0 km. The charging Muskox was a subadult animal that was part of a herd of 9–10 animals that slowly moved through the colony. The fox was observed following the herd for 1 hour and 12 minutes and was never more than 0.5 km away from the herd. Muskoxen were seen in the colony on several occa-

*See Documents Cited section

sions, but the incident reported here was the only time that Muskoxen charged birds.

The observation of the fox killing the goose illustrates that Arctic Foxes occasionally kill nesting geese (as suggested by Syroechkovskiy et al. 1991 and Prestrud 1992). However, considering how seldom this is observed, it appears to be relatively uncommon and most interactions between Arctic Fox and nesting geese are likely non-fatal. This suggests that the high occurrence of goose parts in Arctic Fox diets in some areas (Stickney 1991; Prestrud 1992; Hersteinsson and MacDonald 1996; Bantle and Alisauskas 1998) is mostly the result from scavenging of goose carcasses, or killing of goslings and molting adults during the brood-rearing season.

The observation of the fox taking eggs from geese as they were pushed off nests by a Muskox further illustrates the opportunistic nature of Arctic Foxes and shows that they can learn to associate disturbance with food. Arctic Foxes occasionally take eggs from geese disturbed by human activity (suggested in Prestrud 1992; GS and ML personal observation; R. T. Alisauskas, Canadian Wildlife Service, Saskatoon, personal communication; S. M. Slattery, University of Saskatchewan, Saskatoon, personal communication). However, to our knowledge, this is the first documentation of an Arctic Fox opportunistically taking advantage of disturbance caused by Muskoxen to facilitate its foraging. Thus, it appears as though Arctic Foxes are opportunistic not only in their choice of diets, but also in how foods are acquired.

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Aerial Attacks by Common Ravens, *Corvus corax*, on Adult Feral Pigeons, *Columba livia*

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Hendricks, Paul, and Steve Schlang. 1998. Aerial attacks by Common Ravens, *Corvus corax*, on adult feral pigeons, *Columba livia*. Canadian Field-Naturalist 112(4): 702–703.

Five aerial attacks by Common Ravens (*Corvus corax*) on feral pigeons (*Columba livia*) were observed during 1994–1997 in Missoula, Montana. Four of five attacks involved more than one raven and occurred in winter and early spring; \pm one of the winter attacks was successful. Common features of aerial attacks on pigeons reported here and in the literature include: (1) cooperative hunting, (2) flushing pigeons into the air from roosts, (3) grabbing at the pigeon wings with the bill to bring them down. Our observations, and those in the literature, indicate that aerial hunting of birds by ravens is not restricted to one site. Repeated observation of aerial attacks at one site further suggests that it may occur relatively frequently.

Key Words: Common Raven, *Corvus corax*, feral pigeon, *Columba livia*, aerial attacks, predation, Montana.

The Common Raven (*Corvus corax*) is well-known as an omnivore with opportunistic feeding behaviors (Bent 1946; Heinrich 1989). Items in the diet are acquired through active hunting, kleptoparasitism and scavenging (Temple 1974; Kilham 1985a, 1985b; Gaston and Elliot 1996), and include plant material, insects, other invertebrates, and taxa from all vertebrate classes (see Harlow et al. 1975; White and Tanner-White 1985; Olson 1989; Stiehl and Trautwein 1991; Ratcliffe 1997; Hendricks 1998).

Predation by Common Ravens on bird eggs and nestlings has been witnessed many times (e.g., Bent 1946; Montevocchi 1979; Marr and Knight 1982; Gaston and Elliot 1996), yet there remain few published observations of predation on adult birds in the wild. Ratcliffe (1997) summarized the literature for Britain and Ireland, including an account of a group of ravens capturing Atlantic Puffins (*Fratercula arctica*) as they emerged from their burrows. Eells (1980) observed a raven kill a Northern Flicker (*Colaptes auratus*) after pulling it from its nest cavity, Parmelee and Parmelee (1988) saw a pair of ravens kill two roosting Black-legged Kittiwakes (*Rissa tridactyla*), and Maser (1975) described a successful attack by a pair of ravens on a free-flying feral pigeon (*Columba livia*). Maser (1975) also found a pair of ravens with a recently killed Chukar (*Alectoris graeca*) that he assumed had been captured alive, although he did not witness any pursuit or capture. Tinbergen (1958) reported seeing numerous aerial chases of Rock Ptarmigan (*Lagopus mutus*) by ravens, but apparently he never witnessed an actual kill nor did he provide additional details of the attacks. Temple (1974) considered ptarmigan remains in winter raven pellets he examined to be scavenged rather than the result of predatory behavior. We describe several aerial attacks (including one successful) by ravens on adult feral pigeons. All observations reported here were made in

or near Missoula, Missoula County, Montana, USA (46°00'N 114°00'W).

On 15 February 1995 at 1015 MST, SS observed three ravens pursuing a pigeon that apparently had been flushed from its roost in a chip mill at a log-home building company. The chase was already in progress when first noted, and covered at least 500 m in the air, in which the pigeon made repeated dodges in an effort to evade the ravens. The ravens were spread horizontally, with the flanking birds "herding" the pigeon (perhaps incidentally), as the center raven closed the distance between it and the pigeon. After about 1 minute the middle raven used its bill to grab the right wing of the pigeon, dislodging some of the pigeon's flight feathers. All four birds dropped towards the ground and out of view behind some buildings. When next seen 2 minutes later, the dead pigeon was in the bill of one raven, which had begun eating the carcass and continued to feed for about 20 minutes. Because the kill occurred out of view, we are uncertain which raven ended up with the dead bird. The two ravens without the pigeon remained passively nearby for several minutes before finally departing without gaining access to the dead bird. Several Black-billed Magpies (*Pica pica*) appeared shortly after the kill, but were also unsuccessful in gaining access to the pigeon carcass.

On 1 March 1995, SS observed a pair of ravens fly into one entrance of the chip mill, flushing pigeons from their roost. One of the ravens pursued a pigeon for several seconds but was too slow to catch the bird, and quickly gave up the chase. Another unsuccessful chase by a pair of ravens was observed at the same site on 31 March 1995, although this time the ravens did not enter the chip mill. The previous year (1994) a pair of ravens nested near the chip mill, and on 6 June SS saw one adult of the pair pursue a pigeon for several hundred meters before ceasing with the attack.

On 14 December 1997, PH observed a feral pigeon pursued by two Common Ravens near a city intersection at least 8 km from the previous locality. At that time (13:45) only about 3 m distance separated the pigeon and closest raven as they flew in a nearly straight line about 8-10 m above the ground. Within 5 seconds the raven caught up with the pigeon and struck a glancing blow to one of the pigeon's wings with its bill. The pigeon immediately dropped towards the ground and out of sight behind a hedge, followed quickly by the two ravens. About 1 minute later both ravens flew up without the pigeon and perched on nearby telephone poles. The pigeon was not seen again, and must have evaded the ravens by escaping through the hedge.

There are some common attributes to the attacks by Common Ravens on feral pigeons described here and by Maser (1975). First, most (five of six) attacks were cooperative efforts, involving more than one raven, and the two successful aerial attacks were cooperative. Successful predation of adult birds in the air may be more dependent upon cooperative hunting than are the capture of eggs and nestlings at nests or adult birds at rest. In the successful attack described by Maser (1975) the two ravens shared the prey, whereas the prey was not shared in the successful attack we describe. This difference in food sharing could be attributed to the mating status of the ravens involved. Bent (1946) and Heinrich (1989) indicate that mated pairs share kills. Maser's (1975) attack occurred in May and the two ravens were probably a mated pair. All of the attacks involving more than one raven that we describe occurred in winter and early spring by birds of unknown age and status. The successful attack was made by three birds. Absence of food-sharing by the raven that captured the pigeon indicates it probably was not paired to either of the other individuals.

Second, ravens used their bill to grab a wing in two of the aerial attacks we observed; in both cases the fleeing pigeon dropped to the ground. This form of attack on a pigeon appears effective in ending an aerial chase, although it was not described by Maser (1975) in the successful attack observed by him. Wing-grabbing during aerial attacks by Ravens may not be the only method used for prey capture. Dickson (1969) described an attack on a juvenile Jackdaw (*Corvus monedula*) where a lone Raven apparently used its feet repeatedly in an attempt to secure the victim (described as "clutching" by Dickson). Because there are few accounts of aerial attacks by Ravens on birds, it is impossible to assess the frequency by which Ravens secure prey using either the bill or feet.

Third, hunting Common Ravens often fly at roosting feral pigeons and attempt to force them into the air. At least two of the attacks observed by us and Maser (1975) followed flushing pigeons from roosts. Forcing perched birds from nests is also a common hunting technique for gaining access to eggs and nestlings of prey species (e.g., Marr and Knight 1982; Gaston and Elliot 1996).

Our observations of aerial attacks by Common Ravens on feral pigeons in Missoula suggest that ravens may routinely hunt adult pigeons by flushing them from roosts (as indicated by observations at the chip mill), and that this behavior is not restricted to one site in this area.

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Sixteen Years with a Bald Eagle's, *Haliaeetus leucocephalus*, Nest

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A pair of Bald Eagles on their nesting territory was observed 12 months a year for 16 years. The nest was twice damaged by gales and in each instance the eagles missed a year of breeding. During 16 years 18 young fledged, 1.15 per year, or excluding years with a damaged or incomplete nest, 1.4 per year. Territory was occupied about 10 months a year. Each of the original birds was lost during the period and was quickly replaced. Estimated minimum age at death was 15 years for the female, and 19 for the male, most probable ages 21 and 24 years respectively.

Key Words: Bald Eagle, *Haliaeetus leucocephalus*, nesting behaviour, productivity, longevity, nest site tenacity.

Since 1962 one of us (E.K.) has lived for part of almost every week on the most southwesterly tip of Galiano Island, British Columbia. The area is rocky, precipitous, and supports a forest of mature coniferous trees including Douglas-fir (*Pseudotsuga menziesii*) reaching heights of some 40 m, Grand Fir (*Abies grandis*), Western Redcedar (*Thuja plicata*) and Western Yew (*Taxus brevifolia*), interspersed with scattered trees of Garry Oak (*Quercus garryana*) and Arbutus (*Arbutus menziesii*). Salal (*Gaultheria shallon*) dominates the shrub layer.

The site overlooks the western entrance to Active Pass (48°50'N, 123°18'W), a channel with a minimum width of about 400 m, that separates Galiano Island from Mayne Island. The pass is one of several that carry the immense tidal volume that ebbs and flows twice daily between the Strait of Juan de Fuca and the Strait of Georgia. It is characterized by tidal currents that sometimes reach 7 knots, and result in turbulence, and upwelling. The strait supports a rich fauna and flora of both attached and free-swimming marine organisms. This includes many species of bottom and demersal fish, Harbour Seals (*Phoca vitulina richardii*), California Sea Lion (*Zalophus californianus*), and Steller's Sea Lion (*Eumetopias jubatus*) and the occasional pod of Killer Whales (*Orcinus orca*). It is also the seasonal feeding ground of an assortment of marine birds, including loons, grebes, cormorants, alcids, gulls, diving ducks, and mergansers, often numbering in the thousands.

Through most of the year Active Pass and its cliff-girt shores supports a small resident population of Bald Eagles, but when there is a temporary flush of feed, as when the herring are spawning, as many as 86 adult eagles have been counted at one time (5 March 1981). Immatures were also present but were more difficult to count owing to their cryptic coloration. Prior to 1982, the eagles' nest closest to the Kennedy property was on northern Mayne Island, about 400 m across Active Pass.

The nearest nest on Galiano Island was about 1 km along the island coast to the west. This nest had been active for several years prior to the commencement of the observations reported here.

In 1981–1982 loggers removed the timber from around the Galiano nest tree in which this pair of eagles was raising a single young. As soon as the eaglet was on the wing the trio abandoned the nest site. At that time, in July 1982, two adult eagles and a fledgling arrived in a grove of large Douglas-firs on the Kennedy property. We assume they were the displaced family. After a short stay at their new location they left the region in August and returned to it in October. During the winter the adults engaged in courtship and carried branches first to one tree in the grove, then to another before they settled on a site for a new nest.

The nest is in a large Douglas-fir close to the house and it has been easy to observe the eagles constantly. The Kennedys have made no attempt to conceal themselves or to restrict normal activities of gardening, the use of power equipment, wood-chopping and every-day use of the house and garden. It took the original pair of eagles, and each replacement eagle, between one and two years to become fully used to the Kennedys and their activities.

It soon became possible to associate different call notes with each of the eagles and their many behaviours. Size differences clearly separated the male from the larger female, and subtle differences in appearance, voice cadence, calls, perch selection, and other behaviour distinguished each as individuals. Thus it was possible to say with certainty, for instance, that the eagle that appeared at the nest site in October was the same individual that had left in August. Or that the pair that nested one year was the same pair that nested the subsequent year.

It has been shown, with many species of vertebrates (Dagg and Foster 1976; Bigg et al. 1987;) that careful observation reveals differences that permit identification of individuals. With the eagles, all that

was necessary was to be able to distinguish two birds from each other, and to be able to know at any time whether this was or was not one of the "home" birds. It was not difficult to be confident at this level.

By spring of 1983 they had chosen a nest site and worked steadily at building a nest, completing it a year later, in time to lay at least two eggs in the spring of 1984. First sounds of the eaglets were heard in early June and the two young fledged on 20 and 28 July. The female and young left the area toward the end of August, but the male remained at the breeding area. The female and young returned by 12 October. We have learned to expect this period of absence from the nest site, usually between late August and October, as an annual event. It coincides with the arrival on the Pacific Coast of both Alaska and British Columbia of several million salmon on migration to their spawning grounds in the rivers that flow into the sea along that coastline.

The Galiano nest site is within 110 km of most of the major winter eagle concentration sites documented by Campbell et al. (1990). These are well known for the appearance annually, during the autumn and winter months, of several hundred, to a thousand or more Bald Eagles along the lower reaches of many rivers in which the salmon are spawning. Even closer to the nest site are the Goldstream, Cowichan, and Quinsam rivers, about 45 km distant from Active Pass. Along the lower reaches of the spawning rivers the Bald Eagles gorge themselves on the spawning and dying salmon. A peculiarity of all five species of Pacific salmon (*Oncorhynchus*) is that all individuals die after entering the spawning rivers, whether or not they spawn successfully, thus providing an abundance of carrion. It is tempting to presume that the Galiano eagles were at one of the salmon rivers during their annual "holiday" from the nesting area. However, their period of absence from the nest site is earlier than the major salmon runs of the rivers entering the Strait of Georgia. It seems to us more likely that the Galiano eagles move to the north coast of the Province, where the salmon runs are earlier. Apart from this early autumn absence, the adult pair was always on territory.

The story of this nest and its eagles has been followed from 1982 to 1998. The major features of the history are summarized on Table 1. The eagles that founded the nest were in full adult plumage and had raised an eaglet in 1982. Other observers tell us that their nest tree had been used for about five years. In this species the full adult plumage is reached at six years (Palmer 1988). If the members of the pair at the 1982 nest were the same birds that pioneered the site five years previously their ages when they moved to the Kennedy property were a minimum of 11 years. But if either or both of them were not the originals their ages might have been as little as six or seven years or as much as 11 years old when they built the nest on the Kennedy property.

Discussion

We have assumed that when a member of the pair failed to return to its nest and its mate, it was dead. The original female died, with an eaglet in the nest, in July 1991 at an age of at least 15 years, probably 21 years. The eaglet was raised by the male. The original male died in 1995, at an age of at least 19 years, probably 24 years. In each instance a replacement mate appeared and was accepted in October of the same year.

Twice during the years of observation severe gales during winter and early spring seriously damaged the nest. In one such episode eggs were probably present and were lost. In neither instance was there nesting or renesting in the year of the damage.

During the 16-year history of this nest site 18 young fledged for a mean of 1.15 young per year. Eggs were hatched on 13 years, and resulted in the fledging of five broods of 2 and eight of 1.

In the five years when two young were raised fledging dates differed for the two members of the sibling pair. Fledging dates for two-year-old nests ranged from 5 July to 28 July. The mean difference between the fledging of the two siblings was 5.75 days. Using the earliest and latest fledging dates, and 112 days as the length of the nest period from egg laying to fledging (Palmer 1988), dates of egg deposition ranged between 14 March and 4 April.

The female was almost always absent from the nest site for the "salmon break" for longer than the male. In all years for which we observed dates of departure for both birds, the female left the nest site before the male, and in all but two instances she returned later than the male. In two years the male remained at the nest site without a break. The departure of the young from the nest site in most years coincided with that of the female.

Twice during the study period, the resident pair encountered apparent attempts by other eagles to take over the site. In 1989 in September, with the residents both away on the "salmon break" a pair of adults began using the area. They were quickly displaced when the residents returned. Beginning on 2 November 1997 a stranger eagle began to harass the residents and persisted at it until, on 10 February 1998 two adult eagles were attacking the resident pair without success in displacing them; these efforts continued into March. On the night of 19 April the Kennedys were awakened before dawn by the screaming at the eagles' nest. By daylight the residents were still in possession and the invading eagles were gone. On 14 June a dead and decaying adult eagle was found in the undergrowth near the nest tree, an area seldom visited. Both residents were present at the nest. Circumstances suggest that this was probably the remains of the persistent aggressor, but we cannot be certain.

TABLE 1. Events at Nest Site.

Year	nest events	young	absence from site
1983	nest building, 6 months	0	both: August - October
1984	normal	2 fledged 20 & 26 July	Female and young: 19 August - 12 October Male: remained at site.
1985	Nest damaged by gale, 11 February; new nest built in adjacent tree by August.	0	Female: late August - late October. Male: remained at site.
1986	normal	1	All 3: August - October.
1987	Rebuilt and used 1984 nest	1	Female and young: 24 August - 18 October Male: 31 August - 9 October.
1988	Nest damaged and eggs lost in 23 April gale.	0	Female: mid August - 8 October Male: mid August - 10 September.
1989	repair completed	2 fledged 8 & 14 July	All: 11 August - 5 October.
1990	Some nest improvement	2 fledged 5 & 12 July	1 ad+1Y: 13 August 1 ad+1Y: 25 August Female: back 10 October Male: 10 September.
1991	normal	1	Female lost mid July Male: 15 August - 3 October. New female by 25 October.
1992	normal	1	Female: early August - 24 October Male: 16 August - 2 October.
1993	normal	2	Female + young: 15 August - 26 September Male: 21 August - 24 September.
1994	normal	1 fledged 10 July	All left mid-August Female: back 7 October Male: back 2 October.
1995	normal	2 fledged 23 & 27 July	Female + young: 13 August - 8 October Male: left end August and did not return. New male by 30 October
1996	normal	1 fledged 12 July	Female + young: 15 August - 26 September Male: 18 August - 26 September.
1997	worked on nest	1 fledged 22 July	Female + young: 27 August - 3-4 October Male: 22 August - 3-4 October
1998	outside aggressor at nest 2 November (1997) to 9 April. resident pair prevailed.	1 fledged 29 July	Female + young: 13 August Male: 26 August, both still away at time of writing.

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Records of Intra-guild Predation by Eurasian Lynx, *Lynx lynx*

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A total of eight Red Foxes (*Vulpes vulpes*), and one Pine Marten (*Martes martes*) were killed and consumed by radio-collared Eurasian Lynx (*Lynx lynx*). These observations and those from the literature, suggest that intra-guild predation by Lynx may be common. Such predation may be cause for concern because of the risk of transfer of scabies from Red Fox to Lynx.

Key Words: Eurasian Lynx, *Lynx lynx*, Red Fox, *Vulpes vulpes*, Pine Marten, *Martes martes*, intra-guild predation.

Although it has long been known that carnivores kill, and sometimes eat, other carnivores, the full extent of intra-guild predation has often been ignored (Polis et al. 1989). Recent research has demonstrated that such predation may effect species distribution and conservation (e.g., Hersteinsson and Macdonald 1992; Creel and Creel 1996; Durant 1988). While many cases of intra-guild predation have been documented among North American carnivores (e.g., Stephenson et al. 1991), there has been little study of it in Europe.

From 1995 until 1998 the predation behaviour of Eurasian Lynx (*Lynx lynx*) was studied by snow-tracking and radio-telemetry in a site in southeastern Norway (Hedmark), and during winters 1996 and 1997 in northern Sweden (Sarek). The Hedmark study site consists of a hilly landscape covered with Scots Pine (*Pinus sylvestris*) and Norwegian Spruce (*Picea abies*) forest. The Sarek study site is more mountainous, with forested valleys, pine and birch (*Betula* sp.) covered slopes, and alpine peaks. Both sites have relatively continental climates, with cold winters and warm summers. Snow lies from October

until April (June in Sarek). Roe Deer (*Capreolus capreolus*) and semi-domestic Reindeer (*Rangifer tarandus*) were the main prey species for lynx in the Hedmark and Sarek sites, respectively (Haglund 1966; Dunker 1988).

During the study period, a total of eight carcasses of Red Foxes were found by following lynx tracks in snow, or by searching in areas where radio-monitored lynx were believed to have made kills. In each case it was possible to determine from tracks or observation that the lynx had killed the foxes, and had not simply found them dead. The Pine Marten was found when a radio-monitored lynx was observed making the kill. In five of the six cases where the identity of the lynx killing the fox was known, it was an adult female lynx. The other case was by an adult male. The Pine Marten was also killed by an adult female lynx. Sex could be determined for five of the killed foxes: four of these were male. The marten, and seven of the eight foxes killed were all fully grown. Between 75 and 100% of the available meat was consumed on six of the eight foxes and on the Pine Marten. The two foxes that

TABLE 1. The occurrence of Red Fox and Pine Marten remains as lynx prey from various studies in Europe.

Site	Occurrence (%)	n	Method	Reference
<i>Red Fox</i>				
Finland	1	88	Stomach contents	Pullianinen 1981
Sweden	4	46	Stomach contents	Haglund 1966
Sweden	7	46	Stomach contents	Liberg 1997
Sweden	2	65	Kills — snow tracking	Glöersen 1996
Norway	8	66	Kills — snow tracking	Sunde and Kvam 1997
Norway	2	134	Kills — snow tracking	Dunker 1988
Switzerland	13	194	Kills — telemetry	Capt et al. 1992
<i>Pine Marten</i>				
Norway	2	134	Kills — snow tracking	Dunker 1988
Poland	1	172	Kills — telemetry	Okarma et al. 1997
Poland	1	127	Scat analysis	Okarma et al. 1997

were only partially consumed (5%, 50%) were cases where the lynx were scared away from the kills before they could finish feeding.

Red Foxes have often been reported in other studies of the diet of lynx in Scandinavia and Europe (Table 1). Although foxes usually constitute a low proportion of the lynx diet, that their remains are detectable at all in diet studies indicates that the phenomena of intra-guild predation on foxes is widespread. Unfortunately we do not have precise estimates of Red Fox density so that the effect on their population dynamics cannot be estimated. As lynx occur at very low density (0.3–5 per 100 km²) it is unlikely that they could have the same effect on foxes as do Coyotes (*Canis latrans*) (Peterson 1995). Pine Martens are less often reported as lynx prey (Table 1), which may be due to their ability to utilise trees to escape (Lindström et al. 1995). Although the records of foxes and martens from stomach contents and scats could be due to scavenging, lynx so rarely eat prey that they have not killed themselves (own observations) that the chances of this are low. Other carnivores reported to have been killed by, or appearing in the diet of, lynx include otter (*Lutra lutra*) and Raccoon Dog (*Nyctereutes procyonoides*) (Liberg 1997; Okarma et al. 1997). The fact that all lynx that were not disturbed on their kills consumed most of the available meat on the fox carcasses indicates that foxes are regarded as prey. The consumption of other carnivores killed is not universal among cases of intra-guild predation (Peterson 1995).

Predation on foxes could have negative effects on lynx. Since the mid 1980s there has been an epidemic of sarcoptic mange in the Norwegian Red Fox population (Lindström et al. 1995). Lynx have been recorded to die of mange (two radio-collared and at least four unmarked lynx were infected in the Hedmark study site during this study, five of which died as a result of the infestation). Although the exact mode of infection has not been determined, it seems likely that contact with a freshly killed fox would carry a high risk of exposure. This possibility for parasite/disease transfer following intra-guild predation deserves further research.

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Pack Size and Colour Morphs of One Wolf, *Canis lupus*, Pack in Jasper National Park, Alberta, 1979–1998.

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Dekker, Dick. 1998. Pack size and colour morphs of one Wolf, *Canis lupus*, pack in Jasper National Park, Alberta, 1979–1998. *Canadian Field-Naturalist* 112(4): 709–710.

Over 20 consecutive years, 1979–1998, at one locality in Jasper National Park, Alberta, a pack of Wolves (*Canis lupus*) varied in size from 2 to 13 members, with a mean of 7.9. Of the total of 157 individuals, 73.2% were black, 24.8% grey and 1.9% white.

Key Words: Wolf, *Canis lupus*, pack size, colour morphs, Jasper National Park, Alberta.

In western North America, pelage colour of Wolves (*Canis lupus*) ranges from white to black (Mech 1970). Comparative percentages of black and grey for Jasper National Park, based on field sightings, have been given by several researchers (Cowan 1947; Carbyn 1975; Dekker 1986). This paper reports on the colour and size of one pack in Jasper National Park over 20 consecutive years, 1979–1998.

Study Area And Methods

Jasper National Park (JNP) is mountainous and 10 880 km² in size, extending north to a latitude of 52°29' and south to 52°08'. The study area is at Devona in the lower Athabasca River valley. A description of its landforms, flora and fauna has been given by Holland and Coen (1983) and Holroyd and VanTighem (1983). The area is at a key location in the territory of one pack, locally known as the Devona pack, which could be recognized by pelage characteristics (Dekker 1997). However, in 1998 the study area was used by two different packs. Only the larger pack (7 versus 5 members) was included for the tabulation in this paper. I visited the area for two to four days at a time from late summer to late winter for a mean total of 24 days a year (range 18 to 39). I observed the Wolves through binoculars or a telescope from a semi-open hill overlooking montane meadows and river flats. I used simulated howling as a means to attract Wolves (Dekker 1985). Chi-square tests were used to analyze some results. Visual observations were complimented with track counts and warden sightings.

Results and Discussion

Wolves, varying from single animals to groups of thirteen, were sighted on 108 days. The total number was 429, representing a mean group size of 4.0 animals. Pack size (the largest group seen each of the 20 years) varied from 5 to 13, but dropped to 2 in 1983 (Table 1), possibly because of control measures

on adjacent provincial lands (Dekker et al. 1995). The mean pack size of 7.9 compares to 7.8 (n = 13) in Banff National Park, Alberta, 1996–1998 (Carolyn Callaghan, personal communication). Mean pack size in Denali National Park, Alaska, was 6.7 (n = 112) (Mech et al. 1998).

Of the total number of Wolves in the packs (n = 157), 73.2% were black (Table 1), even though there was wide individual variation in pelage detail from nearly completely black to bluish-grey with black accents. Some black wolves had whitish faces,

TABLE 1. Pack size and colour morphs of Wolves sighted at Devona in Jasper National Park, Alberta, 1979–1998

	Pack size	Colour		
		Black	Grey	White
1979	9	7	1	1
1980	7	5	1	1
1981	9	4	5	—
1982	7	3	3	1
1983	2	1	1	—
1984	6	4	2	—
1985	8	5	3	—
1986	7	6	1	—
1987	9	6	3	—
1988	11	4	7	—
1989	5	4	1	—
1990	9	5	4	—
1991	5	4	1	—
1992	13	13	—	—
1993	7	7	—	—
1994	12	12	—	—
1995	11	11	—	—
1996	8	8	—	—
1997	5	3	2	—
1998 ¹	7	3	4	—
Total (Mean)	157 (7.9)	115	39	3
Colour percentage		73.2	24.8	1.9

¹Two different packs were seen in 1998. A smaller pack that contained two black and three grey animals is not included in this table.

legs or feet. Wolves commonly become paler with age. Captive animals have been known to turn from all-black to bluish-grey or silvery white in as little as two years (Monte Sloan, WolfPark, personal communication). Two black Wolves, captured in Alberta in 1995 and reintroduced into Yellowstone National Park, Wyoming, changed to bluish and silvery grey in 1996 (Doug Smith, personal communication). In this study, one recognisable Wolf became noticeably paler over two years.

The 39 wolves that were classified as grey were typically tan-grey or creamy-white on throat, belly and legs, although they might feature darker accents on head, tail, and along the spine. Three Wolves that were entirely or nearly entirely white were placed in the third category.

The proportion of black, grey, and white in the packs was not random ($P = 0.014$). As pack size varied over the 20 years, the proportion of each colour morph was not constant. The number of grey Wolves varied non-randomly, while black and white were randomly distributed (Black $P = 0.933$ N.S.; grey $P = 0.038$; white $P = 0.556$ N.S.). The black morph clearly dominated pack composition, but the number of greys varied. For five years, grey Wolves were absent, 1992-1996 (Table 1).

The 73.2 % of blacks reported here represents the highest value for the black colour morph ever reported from North America. In large samples from Alaska, British Columbia, and northern Alberta ($n = 254$ to 498), the percentage of blacks was 31-33% (Dekker 1986). In the Alberta Rocky Mountain Parks, melanism among Wolves appears to have always been highly prevalent. Holroyd and VanTighem (1984: 330) stated, although they did not give sample sizes, that the percentage of "pure black Wolves" was 63% in JNP and 72% in adjacent Banff National Park. Somewhat lower values, based on sightings, were given for JNP by Cowan (1947), Carbyn (1975) and Dekker (1986), who calculated the black component respectively as 55% ($n = 80$), 46% ($n = 57$), and 53% ($n = 132$). The 1998 percentage of black Wolves in all of JNP, based on sightings, was 60-65% (Warden Wes Bradford, personal communication). In Yellowstone National Park, where Wolves originating from western Canada were reintroduced, blacks made up 60% of the 1998 population (Douglas Smith, personal communication). In Banff National Park, blacks represented 30% ($n = 101$) from 1996 to 1998 (Carolyn Callaghan, personal communication). In two samples ($n = 126$; $n = 196$) from Denali National Park, Alaska, the percentage of black wolves was 9% (Mech et al. 1998).

Acknowledgments

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Horned Pondweed, *Zannichellia palustris* (Zannichelliaceae), New to the Vascular Plant Flora of the Continental Northwest Territories, Canada, and Deleted from the Flora of the Yukon Territory

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Cody, William J. 1998. Horned Pondweed, *Zannichellia palustris* (Zannichelliaceae), new to the vascular plant flora of the Continental Northwest Territories, Canada, and deleted from the flora of the Yukon Territory. *Canadian Field-Naturalist* 112(4): 711-712.

The first records of *Zannichellia palustris* from the Continental Northwest Territories are documented from just south of Fort Simpson and just north of Fort Good Hope. *Zannichellia palustris* is removed from the flora of the Yukon Territory as a record previously reported as this species has been re-identified as an alga *Nitella flexilis*.

Key Words: Horned Pondweed, *Zannichellia palustris*, Zannichelliaceae, Northwest Territories, Yukon Territory.

Porsild and Cody (1980) suggested that Horned Pondweed, *Zannichellia palustris*, (Figure 1) which they included in the family Potamogetonaceae, should be looked for in shallow, fresh or mildly saline ponds or sluggish streams in the southwestern District of Mackenzie on the basis of a collection from Wood Buffalo Park just south of the Alberta border (water of roadside ditch, Salt Plain 20 miles WSW of Fort Smith, near bridge over Salt River (Figure 2 #1), 59°58'N 112°24'W, W.J. Cody 13737, 19 July 1965 (DAO).

In September 1972, Glenn H. Crum, while conducting a limnology project adjacent to the proposed Northwest Territories Pipeline in the Mackenzie River valley, collected specimens of *Z. palustris* from just south of Fort Simpson (Figure 2, #2) and just north of Fort Good Hope (Figure 2, #3). Data are as follows: District of Mackenzie: scattered along the shore in shallow water, Hare Indian River [66°18'N 128°38'W], Glenn H. Crum 629, 10 Sept. 1972 (WIN, photo DAO); Mackenzie River shore in shallow water near Clark Island [61°50'N 120°56'W], Glenn H. Crum 776, 20 Sept. 1972 (WIN, photo DAO).

Although these specimens were collected long before Porsild and Cody's flora was published in 1980, the authors unfortunately had no knowledge of their existence. *Zannichellia palustris* is therefore new to the flora of the Continental Northwest Territories and Crum's collections are a further extension of the known range northwest of the Fort Smith area of some 1100 kilometers to near the Arctic Circle. It should now be added to the list of rare plants in the Northwest Territories (McJannet et al. 1995).

To the southwest, this species was reported from Kluane National Park in the Yukon Territory (Douglas and Ruyle-Douglas 1978; Cody 1996) and was considered rare in that Territory by Douglas et al. (1981): small pond between Mush and Bates lakes [ca 60°17'N, 137°37'W], Wickstrom 362.1 K-SCL (Canadian Wildlife Service, Winnipeg)



FIGURE 1. Horned Pondweed, *Zannichellia palustris*. [Drawing by Valerie Fulford from Cody (1996)].



FIGURE 2. Distribution of Horned Pondweed, *Zannichellia palustris*, in northwestern Canada (dots 1–3) and location site of the alga *Nitella flexilis* (solid triangle 4) in the Yukon Territory (see text for details).

(Figure 2, #4). To the west in Alaska, Hultén (1968) plotted it from the Seward Peninsula and the vicinity of Norton Sound.

The specimen upon which the Yukon record was based was originally preserved in the Canadian Wildlife Service Herbarium at Winnipeg. This herbarium was broken up at the time of a move and specimens from the Yukon Territory and District of Mackenzie were sent to the Department of Agriculture Herbarium at Ottawa (DAO) and have only recently been incorporated in the collection. The specimen which had been identified as *Zannichellia palustris* has been re-examined by Paul Hamilton and found to be a somewhat similar looking species of an alga (*Nitella flexilis* (L.) Ag.). *Zannichellia palustris* should therefore be removed from the list of rare plants in the Yukon Territory (Douglas et al. 1981) and the flora (Cody 1996).

Zannichellia palustris is a circumpolar species which in Canada occurs from Newfoundland and Nova Scotia to British Columbia and throughout much of the United States. The northernmost site in British Columbia is in the vicinity of Fort St. John (56°15'N 120°31'W) (G. Douglas, personal communication). In Alberta the nearest location to that mentioned by Porsild and Cody (1980) from the Salt Plain southwest of Fort Smith is one at about latitude 54°N near the Saskatchewan border mapped by Packer (1983). In the northern part of its range it is probably often overlooked because of the habitat which does not attract attention any more than the inconspicuous plant which requires close examination to determine whether it is flowering or fruiting and whether or not it is a vegetative pondweed.

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Predation of a Female House Finch, *Carpodacus mexicanus*, by a Gray Squirrel, *Sciurus carolinensis*

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Eason, Perri K. 1998. Predation of a female House Finch, *Carpodacus mexicanus*, by a Gray Squirrel, *Sciurus carolinensis*. *Canadian Field-Naturalist* 112(4): 713–714.

I observed a Gray Squirrel (*Sciurus carolinensis*) capture, kill, and consume a fully flighted female House Finch (*Carpodacus mexicanus*). Gray Squirrels rarely prey on vertebrates, and previous reports of their predation on birds record them eating only birds' eggs and nestlings.

Key Words: Gray Squirrel, *Sciurus carolinensis*, predation, House Finch, *Carpodacus mexicanus*.

Gray Squirrels (*Sciurus carolinensis*) are primarily herbivorous, depending on the reproductive tissues of plants to meet most of their energetic demands. Members of this species do, however, regularly eat at least small amounts of animal material (Nichols 1958; Banfield 1974; Woods 1980; Korschgen 1981). These squirrels have commonly been observed feeding on insects and occasionally on other invertebrates, and invertebrate matter has been found to compose approximately 0–3% of their diet by volume (Layne and Woolfenden 1958; Nixon et al. 1968; Nixon 1970). In contrast, feeding on vertebrates appears to be much less common in this species. Gray Squirrels consume parts of bones that they scavenge to obtain calcium, but actual predation on vertebrates is rare (Faccio 1996). A single instance has been recorded of a Gray Squirrel preying on an independent, active vertebrate. In that case, a squirrel attacked and killed an Eastern Chipmunk (*Tamias striatus*); it was unknown whether the squirrel stalked the chipmunk or caught it opportunistically (Faccio 1996). Squirrels are known to prey upon birds' eggs and nestlings, but have not previously been reported capturing fully flighted birds (Bailey 1923; Woods 1980).

I observed a Gray Squirrel catch a female House Finch (*Carpodacus mexicanus*) in the city of Louisville, Kentucky, at approximately 38° 14'N, 85° 40'W. The incident occurred on an outside balcony of a house in the suburbs, and my observations were made from the lawn at a distance of approximately 6 m from the balcony. The habitat in the area consisted of mowed, grassy lawns containing shrubs and various species of trees, including oaks (*Quercus* spp.), hickories (*Carya* spp.), and Eastern Hemlock (*Tsuga canadensis*). On the balcony were two feeders that contained sunflower seeds and were used by both birds and Gray Squirrels. The balcony is approximately 3 m below the roof line, protrudes 1.5 m beyond the roof line, and has a balustrade that is 1.5 m high. Squirrels use the balustrade to reach the feeders, which are suspended from posts on the balcony. In addition, birds commonly perch on the

balustrade's top rail before and after going to the feeders.

In the afternoon of 4 October 1997, a Gray Squirrel was crouched on the roof of the house and appeared to be watching birds at and around the feeder. The squirrel leapt from the roof of the house to the balcony railing where it landed on the House Finch, which had been perched on the railing. The House Finch called loudly once. The squirrel bit either the back of the finch's head or its neck, which appeared to kill the finch. The squirrel sat for 3–4 sec, and, still holding the finch in its jaws, it then jumped back to the roof of the house and from there to a nearby hickory tree. It carried its prey to one of the lowest branches of the tree (8 m above the ground) and ate the finch. The squirrel fed on the finch for 5 min and then moved higher in the tree with the remains of the prey and presumably continued to eat. No other squirrels were visible while the squirrel was eating its prey and accordingly no competitive interactions were observed; however, by taking the prey item to a tree the squirrel may have been attempting to avoid such interactions. The only remains that I found around the base of the tree were feathers and the finch's lower legs; other parts, however, could have remained in the tree and might have been scavenged by birds or other squirrels in the tree.

At the time the squirrel attacked the finch, there were five other House Finches nearby, three on the feeder and two on the balcony railing. All of these flew away and perched in trees when the squirrel pounced and its prey called; no birds returned to the feeder for at least 30 min.

The squirrel appeared to attack the finch with the intent of preying upon it. There was no obvious food shortage at the time of this incident, as the feeders were full and hickory nuts and acorns were available from surrounding trees. This appears to be the first recorded observation of a Gray Squirrel capturing a fully flighted bird and consuming it. Although this behavior is relatively uncommon, the possibility exists for such predation to increase in frequency.

Further predations may be most likely in suburban habitats, which tend to have both dense squirrel populations and feeders that attract high numbers of squirrels and birds.

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Wood Duck, *Aix sponsa*, Eats Mink Frogs, *Rana septentrionalis*

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Mallory, Mark L., and Roc Larivière. 1998. Wood Duck, *Aix sponsa*, eats Mink Frogs *Rana septentrionalis*. *Canadian Field-Naturalist* 112(4): 714–715.

According to published reports, Wood Ducks *Aix sponsa* rarely eat vertebrates, and there is only one documented account in the scientific literature of Wood Ducks eating frogs. Here we report on a Wood Duck shot in September 1997 near Sudbury, Ontario, that had consumed three Mink Frogs (*Rana septentrionalis*).

Key Words: Wood Duck, *Aix sponsa*, Mink Frog, *Rana septentrionalis*, predation, Sudbury, Ontario.

The Wood Duck (*Aix sponsa*) is a secretive yet ubiquitous inhabitant of wooded swamps and marshes in eastern North America (Hepp and Bellrose 1995). It is one of the most thoroughly studied ducks, in part because numbers of Wood Ducks were very low in the early 1900s and information was needed to develop sound management practices. Many of these studies have examined the diet of Wood Ducks (see Drobney 1990; Hepp and Bellrose 1995). In general, male Wood Ducks eat mostly plant matter throughout the year, whereas females eat mostly plant matter in the fall, but switch to primarily animal matter during the egg-laying stage of the breeding cycle (Drobney 1990). For both sexes, animal matter consists almost entirely of invertebrates, among which aquatic insects predominate.

On 15 September 1997 at 19:45 Eastern Daylight Time, we shot an immature female Wood Duck on a small pond (46° 57' N, 80° 57' W) near Sudbury in northeastern Ontario. The duck appeared to be returning to her roost following late-evening feeding, because her neck was bulging with food. When we examined the contents of the esophagus (including the proventriculus), we found a variety of aquatic

seeds, an adult dragonfly (Odonata; apparently *Aeshna* sp.), an adult waterbug (Hemiptera; *Lethocerus americanus*), and three Mink Frogs (*Rana septentrionalis*). Each frog was nearly identical in size, with a snout-to-vent length of approximately 4.5 cm, a body width of 2 cm, and a depth of 1 cm (hence total volume of about 27 cm³, excluding appendages).

How commonly Wood Ducks consume frogs or other vertebrates is unknown, but the literature suggests that it is quite rare. Bent (1923: 166) stated "... it also obtains small fish, minnows, frogs, tadpoles, snails, and small salamanders", but he provided no data or reference to corroborate this, and it appears to be a conclusion based on the feeding habits and habitat of the duck. Of 413 Wood Duck stomachs examined by Mabbott (1920), only five (1.2%) had remnants of fish, and two (0.5%) had remnants of unidentified frogs. Scheider (1957) reported a Wood Duck feeding on fish in the winter, Bird (1998) reported a young male Wood Duck eating a Bullhead (*Ictalurus* sp.), and Nelson (1944) found the remnants of a White-footed Mouse (*Peromyscus* sp.) in a Wood Duck gizzard collected during the autumn.

The only other reference we found to Wood Ducks eating vertebrates was Bellrose (1980: 194), where he cited a Mississippi study in which "tiny fish" were found in the diet of some ducklings. In fact, in other major reviews of the diet or general biology of this species (Drobney and Fredrickson 1979; Drobney 1990; Hepp and Bellrose 1995; and references therein), invertebrates were the only animals that comprise parts of Wood Duck diets.

Because most published information on Wood Duck diet comes from its principal breeding and wintering range south of Ontario, it is unclear whether our observation represents opportunistic foraging by this particular female on some lethargic frogs (temperature was approximately 10°C), or an occasional feature of Wood Duck diet in this region where wetlands tend to be unproductive (McNicol et al. 1987) and preferred aquatic plant foods may be less available. In Ontario, the Wood Duck is common in the south (where productive wetlands are interspersed among agricultural lands; Ross et al. 1984), but is much less common in the north (on the Precambrian Shield where wetland productivity is substantially lower; McNicol et al. 1987), where it must also compete with other cavity-nesting ducks such as Hooded Mergansers (*Lophodytes cucullatus*), Common Goldeneyes (*Bucephala clangula*) and Buffleheads (*B. albeola*) for breeding sites (Biro 1987). In these northern habitats, Wood Ducks may be forced to consume food items less typical of their principal breeding areas.

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Intertidal Foraging for Pacific Sand-Lance, *Ammodytes hexapterus*, by Birds

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Willson, Mary F., and Robert H. Armstrong. 1998. Intertidal foraging for Pacific Sand-Lance, *Ammodytes hexapterus*, by birds. Canadian Field-Naturalist 112(4): 715-716.

Bald Eagles, Northwestern Crows, Common Ravens, and Glaucous-winged Gulls foraged for buried Pacific Sand-Lance in the intertidal zone near Juneau, Alaska, by digging or disturbing the sand so that the concealed fish emerged.

Key Words: Pacific Sand-Lance, *Ammodytes hexapterus*, Bald Eagle, *Haliaeetus leucocephalus*, Northwestern Crow, *Corvus caurinus*, Common Raven, *C. corax*, Glaucous-winged Gull, *Larus glaucescens*, foraging, southeast Alaska.

Pacific Sand-Lance (*Ammodytes hexapterus*) are an important forage fish for many marine animals in the north Pacific (Willson et al., *manuscript**). In North America, this species ranges from California to the Bering Sea. They are among the most nutritious small fishes (Willson et al., *manuscript**) and they are more rich in energy than "worms", another common intertidal prey (Robinette and Ha 1997). One defensive tactic of this small fish species is to bury itself in soft sand in the intertidal zone. However, there they become vulnerable to attack by several species of birds, including eagles, gulls, and corvids (Robinette and Ha 1997).

Our observations were made at the northwest end of Gastineau Channel, near the mouth of the Mendenhall River, in Juneau Alaska (58° 21' N, 134° 36' W), and at the mouths of rivers flowing into Berners Bay (58° 50' N, 134° 58' W) on several occasions, particularly in April-July in 1985, 1987, 1995, and 1996. In 1995 and 1996 we also recorded seasonal peaks in eagle numbers in these months at the Gastineau Channel site, as Cain et al. (1988*) did previously.

Avian predators were generally able to detect locations where sand-lance were abundant and concentrated their foraging there. We sampled the distribution of sand-lance where the birds were foraging and in randomly selected areas in the intertidal sand flats. Each sample consisted of one shovelful of wet sand ($N > 200$ in both random and foraged areas). On 8 of 10 sampling days, the abundance of sand-lance was 2 to 100 times higher in the areas where birds were actively foraging; in the remaining two cases, sand-lance abundance appeared to be uniformly very low. Buried sand-lance, mostly adults, were markedly more common in April-June than at other times of year; a few juvenile sand-lance appeared in the sands later in the summer.

Bald Eagles (*Haliaeetus leucocephalus*) rapidly patted the loose sand with their feet, shifting their weight from side to side. This activity disturbed buried sand-lance, which emerged from the sand and were seized by the eagles. Up to 85 eagles sometimes "danced" together in a tight cluster on the sands, especially at minus tides. On one occasion, hundreds of living but inactive sand-lance were observed lying in the shallows and on the sand flats after a large group of eagles had disturbed them. Standing eagles also captured sand-lance from shallow water, using bill or feet, without preliminary sand-patting. Prey was eaten quickly, on the spot.

Glaucous-winged Gulls (*Larus glaucescens*) occasionally dug for sand-lance by moving sand to the side with their bills, but they were not seen to capture fish successfully this way. Northwestern Crows (*Corvus caurinus*) and Common Ravens (*C. corax*) also dug for sand-lance in the intertidal, scooping the sand to the side with their bills. Corvids dug 1-8 holes per sand-lance captured ($N = 10$ observations). Prey was sometimes eaten at the site of capture, but crows often flew several meters away from any other birds to consume their prey. Unlike most of the other foragers, crows usually ate their prey piecemeal and therefore required more time to consume the entire fish. Moving away from the other birds probably reduced the risk of prey theft. Other local observers have also noted fish-digging by crows: a group of about 20 crows digging intently for sand-lance was seen by P. Porter (personal communication) at the mouth of Peterson Creek on Douglas Island in Juneau in May 1994. Ravens often carried sand-lance to their nests in nearby forests and probably also stored them in trees near the nest, as they do with other small fishes (herring and eulachon, our observations). By carrying marine prey to the nest, ravens contribute to the flow of marine-derived nutrients to terrestrial ecosystems (Willson et al. 1998).

Acknowledgments

We thank B. H. Marston for helping with the field work, assisted upon occasion by other field crew members.

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*see Documents Cited section.

Large Spotted Turtles, *Clemmys guttata*, Sampled in Central Ontario.

TIM HAXTON

Ontario Ministry of Natural Resources, Box 220, Riverside Drive, Pembroke, Ontario K8A 6X4, Canada

Haxton, Tim. 1998. Large Spotted Turtles, *Clemmys guttata*, sampled in central Ontario. *Canadian Field-Naturalist* 112(4): 717–718.

Two females sampled during a study of a population of Spotted Turtles in central Ontario were larger than previously documented from the wild. Their carapace lengths were 14.25 cm and 13.32 cm respectively.

Key Words: Spotted Turtles, *Clemmys guttata*, record size, Ontario.

A population of Spotted Turtles (*Clemmys guttata*) was studied in Dalton Township, Victoria County (44° 46', 79° 03') in Ontario (Haxton 1997). Thirty-five Spotted Turtles were sampled: nine males (average carapace length (C. L.) = 12.15 cm \pm 0.43 Standard Deviation (SD)); seventeen females average C. L. = 12.14 cm \pm 2.29 (SD)); and nine juveniles (average C. L. = 1.87 cm). Two females sampled during the study were larger than the previous maximum carapace length of 12.7 cm reported for a wild Spotted Turtle (Conant and Collins 1991). A captive Spotted Turtle was recorded to have attained a carapace length of 13.64 cm (Taylor 1991).

The first of the two record-size females was sampled in May 1994, basking beside a small seasonal creek in close proximity to a marsh. The straight-line C.L. measured with vernier calipers (Haxton 1997) was 14.25 cm; plastron length (P.L.) was 12.15 cm; and weight was 410 grams. As the annuli were worn off the plastron, age could not be estimated. The second was sampled during a mild spell in January 1995 (maximum observed daily air temperature 10°C), submerged beneath the surface of the water along with another Spotted Turtle which had a transmitter (Haxton 1997). The female's C.L. was 13.32 cm; P.L. 11.21 cm; and weight 380 grams. The annuli were not worn. A cast made of the plastron (Galbraith and Brooks 1987b) gave a minimum estimated age of 27 years based on a count of the number of annuli (Sexton 1959). This age estimate was considered a minimum as annuli are not necessarily laid down every year and, as a result, the actual age may be underestimated (Ernst 1975; Galbraith and Brooks 1987a, 1989; Lovich et al. 1990). By reconstructing the growth of the turtle using the Sergeev formula (Sergeev 1937; Ernst 1975; Galbraith et al. 1989), the age of maturity was estimated to be 13 years based on a decrease in growth rate after attainment of maturity (Galbraith et al. 1989). Her C.L. at maturity was estimated to be 11.73 cm. Neither turtle displayed any evidence of missing appendages or injuries.

Larger body sizes in northern climates has reported for several species of turtles (Brooks et al. 1992;

St. Clair et al. 1994; Edmonds and Brooks 1996). Hypothesis to explain larger body size in northern populations have been (1) to achieve greater reproductive output (Brooks et al. 1992; St. Clair et al. 1994; Edmonds and Brooks 1996); (2) better survival during longer winter due to the greater energy reserves (Galbraith et al. 1989; Brooks et al. 1992); and (3) reduce risk of predation (Gibbons 1987; Brooks et al. 1992). As wild Spotted Turtles can live in excess of 30 years (Ernst et al. 1994) and mortality rate of turtles is inversely proportional to their age (Iverson 1991), it is likely that longevity in conjunction with continuous slow growth enabled these turtles to attain the size observed.

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News and Comment

Yet Another Milestone for William James Cody

Few organizations run entirely by volunteer effort are fortunate to have an asset like William (Bill) Cody. The Ottawa Field-Naturalists' Club recognized this in 1979, when Bill was awarded an honorary membership for a remarkable 33 years of contribution to the Club and Canadian botanical science (*Canadian Field-Naturalist* 94(3): 345). After what seemed like only a short time later, the Editor noted the forty-year landmark of intense service with a short commentary on Bill's contributions (*Canadian Field-Naturalist* 101(2): 159-160).

With the coming of 1998 the Club realized that Bill has been serving on Council and as Business Manager of the *Canadian Field-Naturalist* for an incredible 50-year period! Such long-term service and dedication is unprecedented in the history of the Club and is not likely to ever be repeated. The titles of office do not reveal the extent to which Bill has laboured for the Club. One cannot completely list the jobs that he has taken on (even Bill cannot remember them all), many of which are among the most distasteful and time consuming (imagine the years of dealing with government forms for postage rates, charitable status, etc.). Executive officers have come and gone, *Canadian Field-Naturalist* editors have come and gone, Council is re-elected every year, but Bill Cody continues as a major constituent of the glue that keeps the Club together and keeps it, and its scientific publication, running smoothly.

Amid the ice storm of 1998 discussions in the awards committee and Council were held as to what, if anything, could be done to show the Club's appreciation and sincere thanks for such remarkable dedication and achievement. One has to appreciate the difficulties encountered in discussing and planning any Club activity without Bill knowing all about it, so intricately is he involved with all aspects of Club functions. It was quickly and unanimously decided that something very special and unprecedented had to be done. It was resolved that a special reception would be organized to mark this half century anniversary.

On 18 September 1998, from 7:30-10:30 PM, a reception was organized at the Central Experimental Farm in Ottawa as a small token of our appreciation to Bill. The aim was to keep the event as informal as possible in keeping with Bill's humble character. Short tributes were, however, presented by past-presidents Bill Gummer and Frank Pope, putting



Bill Cody with plaque presented by The Ottawa Field-Naturalists' Club 18 September 1998.

Bill's activities into perspective with the Club's history. Francis Cook, present editor of *The Canadian Field-Naturalist*, also spoke on the vital role Bill has played in the development and continuing publication of one of the oldest scientific journals in Canada during the terms of five different Editors. Dave Moore, OFNC president, was master of ceremonies and read some of the many letters of tribute sent by members from across Canada who were unable to attend, but wanted to recognize the remarkable contributions Bill has made.

As part of the ceremonies an exquisite carving of a Black-capped Chickadee, by Ellaine Dickson, was presented to Bill by its carver and a plaque was presented by Stephen Darbyshire (chair of the OFNC Awards Committee). The plaque features a drawing of the Walking Fern (*Camptosorus rhizophyllus* (L.)

Link), rather fitting in view of his interest in ferns and his long, unbroken service. The plaque bears the following inscription: "**This plaque is presented to William J. Cody by The Ottawa Field-Naturalists' Club in recognition of 50 years outstanding service as Council Member and Business Manager of The Canadian Field-Naturalist (1948–1998), September 18, 1998**".

About 60 people, including many of the Club's past presidents and officers, attended the reception. Many of Bill's family were also able to join us, although the one note of sadness was that Lois, Bill's

wife who died in March, was not able to take her well-deserved share of the glory.

This evening was no indication of the end of an era. Bill Cody is still attending meetings, still picking up the Club's mail, still skillfully managing CFN business, still writing Club cheques and still guiding and inspiring other Club workers. The question is, "What are we going to do for the 60th anniversary?"

STEPHEN DARBYSHIRE
Chair, Awards Committee

Notices

Erratum The Canadian Field-Naturalist 112(3)

On page 544 on the notice of *Catalogue of Type Specimens in the Vascular Plant Herbarium of Agriculture and Agri-Food Canada in Ottawa* the web page as given is erroneous. The correct entry is now: <http://res.agr.ca/brd/dao/>

Rana-Saura: Amphibian population monitoring program; Atlas of amphibians and reptiles of Quebec

Volume 5, Number 1, September 1998, contains the latest progress on the monitoring program and the Atlas of amphibians and reptiles of Quebec. Eleven anurans and 10 salamanders were observed at least once in 1997 and the list of the nearly 270 who participated in monitoring and atlasing are given, along with a few newsworthy items of general interest to herpetologists. Particularly worth noting are a web site on deformed amphibians: http://www.hartwick.edu/biology/def_frogs/index.html; and one on the Northern Leopard Frog: <http://www/afternet.com/~teal/sfrog.html>.

For more information contact David Rodrique, Saint Lawrence Valley Natural History Society, 21125 ch. Ste-Marie, Ste-Anne-de-Bellevue, Quebec H9X 3L2; e-mail ecomus@total.net.

Ontario Natural Heritage Information Centre Newsletter

Volume 4 Number 2, contains: Data Loading Completed for Vulnerable, Threatened and Endangered (VTE) Plants, Amphibians, and Reptiles; Changes to Ontario's Rare Plant List; MNR's Maple Wildlife Research Station Herbarium Finds a New Home; NHIC Collaborates on Botanical Status Reports; NHIC Assists Waterloo Region with Review of Significant Plants List; NHIC Contributes to the "Ontario Plant List"; International Blanding's Turtle Conservation Conference; Frogwatch-Ontario; NHIC Participates in Eastern Massasauga Conservation and Management Symposium; Marine Park Proposal for Lake Superior; Historical Prairie and Savannah Mapping Project; Rare Communities of Ontario: Great Lakes Arctic-Alpine

Basic Bedrock Shoreline; Ecological Land Classification for Southern Ontario: First Approximation and Its Application; Community-based Biodiversity Conservation in Northwestern Lake Superior Landscape; Natural Areas Database and Wetlands Data; NHIC Participates in Ecoregional Planning for the Great Lakes Basin; Alvar Stewardship Packages; Focus on Helen Godschalk; News and Notes; Staff Notes; Publications; NHIC Information Products; and NHIC Staff List.

Copies can be obtained from the Natural Heritage Information Centre, P. O. Box 700, Peterborough, Ontario K9J 8M5; the web page is <http://www.mnr.gov.on.ca/MNR/nhic/nhic.html>

Froglog: Newsletter of the Declining Amphibian Populations Task Force (DAPTF)

Number 29, October 1998, contains: DAPTF Seed Grants 1998 report; The Decline of Amphibian Diversity in Exploited Forests (Nguyen Quang Truong); New Records of "Declining" Frogs in Queensland, Australia (Jean-Marc Hero, Harry Hines, Edward Meyer, Clare Morrison, Craig Streatfeild and Lewis Roberts); Report of the DAPTF Atmospheric and Global Change Working Group (Cindy Carey); Donations; Publications of Interest. Included is a "Amphibian Mortality Information Sheet" of guidelines for dealing with dead and diseased amphibians that are found during a suspected disease outbreak or amphibian mortality event. Malformed amphibians in the USA and Canada can be reported to the North American Reporting Center for Amphibian Malformations at: <http://www.npwr.usgs.gov/narcam>

Number 10, December 1998, contains: SSC [IUCN Species Survival Commission] Amphibian Network to be Restructured; US Government Takes Big Leap [formation of federal Taskforce on Amphibian Declines and Deformities (TADD)]; Status of Amphibians in Bermuda; Disease and Pathology Working Group Report: A breakthrough in the hunt for a cause of amphibian declines; Disease & Immune Function Workshop; Swiss study highlights a major problem in the study of amphibian declines.

Froglog is available from Editor John W. Wilkinson, Department of Biology, The Open University, Walton Hall, Milton Keynes, MK7 6AA, United Kingdom; e-mail: daptf@open.ac.uk and on the World Wide Web at the following URL: <http://acs-info.open.ac.uk/info/newsletters/FROGLOG.html>

Marine Turtle Newsletter

Number 82, October 1998, 28 pages, features articles: More Kemp's Ridley Turtles Return to South Texas to Nest; Site Fidelity and Size Frequencies of Juvenile Green Turtles (*Chelonia mydas*) Utilizing Near shore Reefs in St. Lucie County, Florida; and notes: Tag Recovery Supports Satellite Tracking of a Green Turtle; Green Turtle Tagged in Brazil is Recovered in Trinidad; Olive Ridley Tagged in Orissa Recovered in the Coastal Waters of Eastern Sri Lanka; as well sections on Meeting Reports, Announcements, News & Legal Briefs, and Recent Publications. The Marine Turtle Newsletter is edited by Brendan J. Godley and Annette C. Broderick who have

moved since the last issue to: Marine Turtle Research Group, School of Biological Sciences, University of Wales, Swansea, Singleton Park, Swansea SA2 8PP Wales, UK; e-mail MTN@swan.ac.uk; Fax +44 1792 295447.

Subscriptions to the MTN and donations towards the production of MTN and its Spanish edition NTM [Noticiero de Tortugas Marinas] should be sent c/o Chelonian Research Foundation, 168 Goodrich Street, Lunenburg, Massachusetts 01462 USA; e-mail RhodinCRF@aol.com; Fax + 1 978 840 8184. MTN website is: <http://www.seaturtle.org/mtn/>

Wild Travelers: Migratory Wildlife Shared by Canada, United States, and Mexico

This attractive 40-page booklet with colour illustrations briefly covers 284 species of birds (37 families), 19 fish, 4 sea turtles, the Monarch Butterfly, 4 bats, and 9 marine mammals (8 whales and 1 seal), all of which are migratory between Canada and Mexico (and sometimes beyond). It is available from any of the co-sponsors: Publications Canadian Wildlife Service, Environment Canada, Ottawa, Ontario K1A 0H3 Canada [or contact Mark Hickson by

phone 819-997-1095; e-mail Mark.Hickson@ec.gc.ca]; The United States Fish and Wildlife Service, Office of Migratory Bird Management, Arlington Square, Room 634, 4401 N. Fairfax drive, Arlington Virginia 22203 USA; or Direccion General de Vida Silvestre, Instituto Nacional de Ecologica - SEMARNAP, Avenida Revolucion #1425, nivel 19, Colonia Tlacopac, San Angel, Mexico D.F. 01040

Freshwater Fishes of Canada: The fifth reprinting

This classic work by W.B. Scott and E. J. Crossman has now been reprinted. It was originally published in 1973 and reprinted unchanged in 1975. The second reprinting in 1979 contained supplementary information included as "Author's Comments, 1979, pages xiii-xviii. Further reprints were issued in 1985 and 1990. The present, fifth reprinting, includes all the information from the previous printings plus a further supplementary "Author's Comments - 1998". A new, fully revised edition is being prepared and publication is "expected" between four to six years. It will include post-1973

species and update species range maps. The present reprint is xxiv plus 966 pages and has descriptions of 181 species. Colour illustrations are not included. The price is \$175.00 Canadian or US\$125 for the United States and other countries. Students (order must be accompanied by a photocopy of a valid student card) may obtain it at \$149.80 (Canada) or US\$100.00 (United States). Postage & Packaging charges are for Canada \$10.00 for the first copy and \$5.00 for each additional copy, for the United States US\$10.00 and US\$5.00 for each additional, for Overseas US\$18.00 and US\$10.00

each additional (for private purchasers, postage and packaging are included in the purchase price). Available from Galt House Publications, Ltd., 2062 Oakmead

Boulevard, Oakville, Ontario L6H 5B4, Canada, Phone (905) 849-0014; Fax (905) 849-1102; e-mail: emmersons@haltonbe.on.ca

Global Biodiversity Fall 1998

Volume 8, Number 2, of Global Biodiversity includes: Features - The business of environmental law (Peter K. Krabn); Conserving the Gray Wolf in Ontario (Dennis Voigt and Maria de Almeida); Editor's Notebook (Surface tension); Portrait of Biodiversity (Lamp shells); Biodiversity News (10 years of Environmental Choice; Indonesian fire damage; Bio-piracy in India; Canada's old-growth coral groves; US organic food and farming; Surinam's rain forest preserve) Forum (The power of seeds); Successes and Initiatives (Rare seabird studied; Canopy walkway beckons; environmentally friendly bargain shopping); Cyberdiversity; Conference Report

(Biosafety Working Group); Meetings; Book Reviews; The Last Word: Taking stock... Systematics, classifying and naming the earth's biota, is the first step to understanding how to care for our planet (Robert S. Anderson).

Global Biodiversity is edited by Don E. McAllister, and the Managing Editor is Judy Redpath. It is published quarterly by the Canadian Museum of Nature, P. O. Box 3443, Postal Station D, Ottawa, Ontario K1P 6P4, Canada. For Subscription Sales contact Louisa Guglielmo, telephone: (613) 566-4784 or 1-888-437-6287; Fax: (613) 566-4763; e-mail: <biodiv@mus-nature.ca>.

For further information, access URL: <http://www.nature.ca>

Sea Wind: Bulletin of Ocean Voice International

Volume 12, Number 3, 36 pages, July-September 1998, includes articles on: Coral reefs and global change: Impacts of temperature, bleaching, & emerging issues; The Women's Fisheries Development Section of the Secretariat of the Pacific Community; Jubilee 2000 - Celebrating the Second Millennium by cancelling debts to the world's poorest - Y2K-JB; A surfer's view of the ocean; The Strait of Georgia Pacific herring controversy; Coral Bleaching Survey; Seas the day: A call for action; Sea News; FAO

consultation agrees on a global plan for sharks; On the Net; Booke Nooke; Ocean Voice International Membership Application Form.

Sea Wind is available though membership in Ocean Voice International P. O. Box 37026, 3332 McCarthy Road, Ottawa, Ontario K1V 0W0, Canada; e-mail: mcall@superaje.com; World-Wide Web site: <<http://www.ovi.ca>>.

American Society of Mammalogists Annual Meeting 1999

The 79th Annual Meeting of The American Society of Mammalogists will be held 20-24 June 1999, at The University of Washington, Seattle, Washington, USA. This year's program includes a keynote address by Dr. Thomas Kunz of Boston University (1998 recipient of the C. Hart Merriam Award) and special symposia on marine mammals ("Marine Mammals: The Next Century", Dr. Paul Anderson, chair) and methods for studying bats ("Acoustic Sampling of Bats: Use of Modern Bat Detectors", Dr.

William Gannon, chair). The meetings will also feature the usual ASM socials, ideal for professional interaction. Contributed papers will address all aspects of mammalian biology. For more information, contact Dr. Steven West (College of Forest Resources, University of Washington, Box 352100, Seattle, Washington 98195-2100; phone 206-685-7588; FAX 206-685-0790; e-mail sdwest@u.washington.edu).

American Herpetological and Ichthyological Societies Meeting 1999

A joint meeting of the American Society of Ichthyologists and Herpetologists (79th Annual Meeting), American Elasmobranch Society (15th Annual Meeting), Herpetologists' League (47th Annual Meeting), Society for the Study of Amphibians and Reptiles (42 Annual Meeting) will be held at the Pennsylvania State University, State College, Pennsylvania, USA, 24-30 June 1999. Symposia will be "The Evolution and Higher Systematic Relationships of the Chondrichthyes"; "Elasmobranch Genetics"; "Variation in Lizard Social Behavior: Individuals, Populations, and Species";

"Symposium in Honor of Dr. Richard Etheridge", "An *Anolis* Symposium"; and "Reproductive Success in Salmonids". There will be contributed presentations as well, both oral and poster. Abstract submission deadline was 1 February 1999 (a maximum of only 650 oral presentations could be accepted), abstract changes accepted until 15 March 1999, Preregistration deadline 23 April 1999. For further detail see web site: <http://www.outreach.psu.edu/C&I/ASIH/> or phone 1-800-PSU-TODAY (in the United States) or 1-814-865-6585 and ask for ASIH operator.

Canadian Amphibian and Reptile Conservation Network Meeting 1999

The next annual meeting of the Canadian Amphibian and Reptile Conservation Network/Reseau Canadien de Conservation des Amphibiens et des Reptiles will be hosted by the Ministère de l'Environnement et de la Faune du Québec and be held in Québec City, Québec, Canada, 15-18 October 1999. This meeting will cover all aspects of the conservation biology of amphibians and reptiles and herpetological research, including the IUCN/SSC Task Force on Declining Amphibian Populations in Canada. As well as contributed papers, there will be a symposium "Perspectives on Herpetological Education and Its

Relation to Conservation Biology" and field trips for local herpetofauna to Cote de Beaupre & Cap Tourmente and for the Goose migration on the North Shore of the St. Lawrence River. Papers can be in English or French and there will be simultaneous translation. For information contact the local co-chairs: Jacques Jutras (418) 521-3940, extension 4456 (e-mail: jacques.jutras@mef.gouv.qc.ca); and Martin Ouellet (514) 398-4086, extension 3190 (e-mail: mouell9@po-box.mcgill.ca); or Stan A. Orchard (re: symposium) (205) 595-7596 (e-mail: sorchard@islandnet.com).

Canadian Association of Herpetologists Bulletin

Volume 12, Number 2, fall 1998, leads with reports of Meetings: ASIH/SSAR/HL/AES/CAH 1998 in Guelph (Tana McDaniel); The 1998 Joint Meetings Conference in Guelph: The Good the Bad and The Ugly (Natalie Helferty); CARCN/DAPCAN '98, Saskatoon (Kevin Judge); More DAP? The Declining Amphibians Populations Workshop at the National Science Foundation, Washington, DC, May 1998 (David M. Green); Biology and Conservation of *Clemmys* [Notice of forum as part of the SSAR/HL/ASIH annual meetings at Penn State University in State College, Pennsylvania, during 24 to 29 June 1999; contact Dr. James Harding at harding@pilot.msu.edu]; Second International Symposium and Workshop on the Conservation of the Eastern Massasauga Rattlesnake held at Metro Toronto Zoo October 2, 3, 1998 (Robert Wilson). A Features section has contributions on Forestry Practices and Amphibian Populations: The Effects of Clear-cut Timber Harvest on the Movement Patterns of Tailed frogs (*Ascaphus truei*) (Excerpts from the Tailed frog Project Progress Report - October 1998) (Brent M. Matsuda and John S. Richardson); Frogs, Fire, and Forestry (Juanita M. Constible); Tailed Frogs (*Ascaphus truei*, Stejneger) in Natural and Managed Coastal Temperate Rainforests of Southwestern British Columbia, Canada - Abstract (Tanya R. Wahbe); Movement Patterns and Dispersal Abilities of Tailed Frogs (*Ascaphus truei*) in Southwestern British Columbia and Southern Oregon - Ph.D. Research in Progress (Tanya R.

Wahbe); Forest Area Effects on Wood Frogs (Elke L. Wind, Fred L. Bunnell, and Chan-McLeod). An Articles section contains: The Effects of Elevation, Soil Characteristics and Habitat Components on the Distribution of *Plethodon cinereus* (Sarah M. Holt); Rideau River Biodiversity Project: an initial report on the Rideau River Biodiversity Project (Francis Cook, Fred Schueler and Michael Rankin). Publications of Interest includes both recent and used herpetological books available (Jon Davidson) and Amphibians in Cyberspace! (David and Carolyn Seburn) [Gives the website permanent address: <http://www.cciw.ca/ecowatch/dapcan> for the Canadian Amphibian and Reptile Conservation Network in association with the Biodiversity Convention Office and the Ecological Coordinating Office (EMCO). This site features an Amphibian Tour of Canada with, for each species, a colour photo, national distribution map, audio file of the call (where appropriate), and text on basic life history and conservation issues pertaining to the species, a key some basic information on amphibian biology, a glossary of terms, a suggested reading list and information on CARCN, DAPCAN, and the CAH.

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Accounts of Famous North American Wolves, *Canis lupus*

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We examined historical accounts of 59 famous North American Gray Wolves (*Canis lupus*) reported during the late nineteenth and early twentieth centuries. Fifty of the 59 wolves were purportedly responsible for great losses to livestock, but for 29 reports, evidence suggested that ≥ 2 wolves (e.g., packs) were responsible for the purported kills; in addition, seven wolves had traits that suggested they were hybrids with dogs, and one wolf was probably not from the area where the damage purportedly occurred. Reported livestock losses, especially to Longhorn cattle, from individual wolves appeared excessively high in relation to current literature. Most famous wolves were old and/or impaired from past injuries: 19 were reportedly ≥ 10 years old, 18 had mutilated feet from past trap injuries, and one had a partially severed trachea from being in a snare. Old age and physical impairments probably contributed to livestock depredations by some famous wolves. Several accounts appeared exaggerated, inaccurate, or fabricated. Historical accounts of famous wolves should be interpreted with great caution, especially when considering impacts of wolf reintroductions or when modeling predation rates.

Key Words: Gray Wolf, *Canis lupus*, damage, hybrids, livestock depredations, North America.

The largest control effort ever waged against wolves (both Gray Wolves [*Canis lupus*] and Red Wolves [*C. rufus*]) took place in the United States and Canada in the nineteenth and early twentieth centuries (McIntyre 1995). Wolf control was justified, in part, by accounts of famous damaging wolves (Lopez 1978). We found accounts of 59 famous Gray Wolves which have served as the basis for predictions of livestock depredations and human fear of wolves, especially when wolves have been considered for reintroduction into areas where they have been extirpated (Bednarz 1988; Bennett 1994; McIntyre 1995; Lohr et al. 1996; Pate et al. 1996). These accounts have been cited in numerous publications and generally have been accepted by the public as valid, with little effort to scrutinize their inherent problems and inconsistencies.

The high degree to which accounts of famous wolves have been accepted by the public is reflected in statements made at public hearings in Montana on the Wolf Environmental Impact Statement and possible reintroductions (McIntyre 1995). In addition, Lopez (1978: 191–194), in his critical assessment of the relationships between wolves and humans, listed 25 “outlaw Wolves” and did not challenge accounts of damage they caused. Mech (1970: 327) indicated that “a long list of notorious wolves... earned reputations during the settlement of the United States as possessing almost supernatural qualities allowing them to outwit even the best trappers.”

Seton (1898, 1929, 1937), Carhart and Young (1929), Graham (1938), Young and Goldman (1944), Young (1946, 1970), Wiley (1954), and Brown (1983) provided accounts of famous wolves

which have had profound effects on public attitudes toward wolves in North America. Other authors have reported on locally famous wolves (Day and Nelson 1928; King 1965; Yost 1970; Wilson 1985; Enright 1992) impacting perceptions regionally. Accounts of famous wolves are scattered through the scientific and popular literature, but are unavailable to most readers. These accounts have been cited in numerous publications and have been quoted in United States Congressional Hearings supporting predator control [United States House Committee on Agriculture, Hearing on control of predatory animals. 1930. 71st Congress, 2nd Session, Washington, D. C.; and United States Senate Committee on Agriculture and Forestry, Hearing on control of predatory animals. 1931. 71st Congress, 2nd and 3rd sessions, Washington, D. C.], with little effort to critically address their inadequacies. A comprehensive review of these accounts has not been published. The purpose of this paper is to summarize the recorded history of famous North American Gray Wolves and to evaluate the credibility of this literature.

Methods

We used accounts by Seton (1898, 1929, 1937), Carhart and Young (1929), Graham (1938), Young and Goldman (1944), Young (1946, 1970), Wiley (1954), Brown (1983), Bennett (1994), and McIntyre (1995) as the basis for most of this report. Reports for other famous wolves were found by searching cited literature, conducting a thorough literature search through major journals and abstracting services, searching wildlife damage control records in

TABLE 1. Additional famous damaging wolves for which limited information is available.

Wolf	Location	Source	Remarks
Two Toes	Colorado	Peake 1937	Killed in 1916
Old Sister	Colorado	Peake 1937	Damaged cattle from 1911 until 1923
Spring Creek Wolf	Colorado	Gish 1978	Killed in 1909
Truxton Wolf	Colorado	Lopez 1978	
Virden Wolf	Manitoba	Lopez 1978	
Ghost	Montana	King 1965	White female, mated with Shepherd dog
Lefty of Fort McGinnie	Montana	King 1965	Left front foot missing, killed in 1924 or 1925
Old Cripple Foot	Montana	King 1965	Killed livestock worth > \$20 000
Pryor Creek Wolf	Montana	Young and Goldman 1944	Skilled at avoiding traps
Big Foot	Wyoming	Day and Nelson 1928	
Cushion Foot	Wyoming	Day and Nelson 1928	
Five Toes	Wyoming	Day and Nelson 1928	
Red Flash	Wyoming	Day and Nelson 1928	Glossy red-tipped fur, probably wolf \times dog hybrid
Scar Face	Wyoming	Day and Nelson 1928	
Two Toes	Wyoming	Day and Nelson 1928	

the United States National Archives in Washington, D.C., contacting professional colleagues, and searching and contacting local and regional newspapers.

We present detailed accounts of individual wolves as presented in both the scientific and popular literature, and then analyze their accuracy based upon our current understanding of wolf biology. These accounts are presented by state or province where the wolves spent most of their lives. Some wolves ranged over parts of two states or between the United States and Mexico, and these are cross referenced between states and countries. Table 1 lists additional damaging wolves for which only limited information was available.

Accounts

Arizona

Aguila, also known as *Old Aguila*.

Brown (1983: 158) stated that this wolf was the "...most famous Arizona wolf." The sex of the wolf was unclear. Young (1970: 63) indicated it was a male, and Musgrave (1923) referred to it as "he", while Brown (1983: 158) referred to it as "she." The *Aguila* Wolf was whitish in color. *Aguila* ranged the desert country, reportedly at "eleva-

tions...far lower than is normal for Gray Wolves" (Gish 1978: 177) in Maricopa County west and north of Wickenburg, Arizona for eight years, 1916-1924. During one night the *Aguila* Wolf reportedly killed 65 sheep and, at another time, 40 (Young and Goldman 1944: 276; Brown 1983: 157-158). Four ranchers claimed *Aguila* killed cattle and sheep worth at least \$25 000 (Gish 1978). A bounty of \$500 was paid to Charlie Gillham when he killed the wolf in 1924. This was one of the largest bounties ever offered in Arizona.

Chiricahua Wolf.

This wolf of unknown sex ranged the full length of the *Chiricahua* Mountains for at least four years (probably 1912-1916) and was killed by A. W. Mills in the *Chiricahua* Mountains in June 1916 (Brown 1983). The *Chiricahua* Wolf reportedly remained alone even though packs of wolves moved through from Mexico. This wolf reportedly never joined other packs for any length of time. The *Chiricahua* Wolf was reported to have killed a yearling heifer or steer about every four days, but never returned to the carcass of an animal it killed (Brown 1983: 157). From each kill the wolf ate about 7 to 8 kg of meat (Gish 1978).

Old One Toe.

This wolf ranged along the Mexican border near Ruby in Santa Cruz County during the early 1900s (Brown 1983). Old One Toe was identified by his characteristic track and the manner he attacked livestock. The wolf reportedly ripped out the flanks of cattle so that the bowels came out, then it followed the injured animal a day or two until it died and then fed upon it (Gish 1978). Biological Survey hunter Bill Casto caught the wolf in a trap, but it escaped leaving two toes in the trap. A second Biological Survey hunter pursued the wolf for several more years before he finally killed it.

Spring Valley Wolf.

Possibly two wolves, but sex and dates of depredations were not provided. According to Musgrave (1921) the Spring Valley Wolf was actually two wolves that ranged (sometimes together, although more often separately) from the Grand Canyon to Kendrick Mountain for 4-5 years. The darker, younger wolf caused serious losses to cattle and sheep; it was killed by a rancher named Sanderson in 1920 or 1921. The second Spring Valley Wolf, which was older and almost white, was poisoned by agent Willis in 1920 or 1921 while he was hunting Coyotes (*Canis latrans*). This white wolf reportedly killed livestock valued at \$2000 to \$2500 per year. It was reported to have visited people's back yards and played with ranch dogs (Musgrave 1921; Gish 1978; Brown 1983: 155-156).

Colorado

Big Foot, also called Terror of the Lane Country.

This male wolf ranged the oil shale country for 17 years (Young 1970: 196) near DeBeque, Colorado in winter and during spring moved to a semi-desert area south of Grand Junction (Young and Goldman 1944: 283-284). During 1921, E. J. Currier, Jr., of Currier Brothers, Grand Junction, claimed that Big Foot and his mate killed 40% of about 100 calves on the range, plus a number of yearling cattle (Young 1970). Currier indicated that the year before (1920) something "happened" to about half the calves (possibly about 50). Big Foot and his mate were trapped and killed during spring 1922.

Gray Terror.

According to Carhart and Young (1929: 205-209) Gray Terror was born in the Burns Hole Country of Colorado, then dispersed north to the Neversummer Mountains of Wyoming where he lived as an adult. Young said the wolf returned to the Burns Hole Country two years after Old Lefty was killed there (see description of Old Lefty below in this section). This male wolf reportedly had a peculiar method of killing cattle (Young 1970: 209-212). Three cattle which had been attacked by this wolf were ripped and torn, and lacerated with great chunks of flesh ripped from the rump, and had bitten noses, chewed ears,

and ripped tails. A U.S. Forest Service ranger familiar with predator attacks said the damage appeared to be from dogs, not wolves. Also, a rancher, who had been president of the Colorado Stock Growers Association, felt strongly that the killing had been done by dogs. However, such attack characteristics have been reported for Bison [*Bison bison*] (Carbyn et al. 1993: 206-208). Young (1970: 212) said calves were most commonly attacked, but deer (*Odocoileus* sp.), and adult cattle were also attacked, mostly for pleasure. Young (1970) noted that Terror killed a male Coyote when the male and a female came close to him while he was feeding at a fresh kill. According to Young (1970: 213), Gray Terror "was one of the most fiendish, most heartless killers that ever engaged the attention of Biological Survey hunters." In contrast to the opinions of others, Biological Survey hunter, Bill Caywood concluded that Terror was a wolf and said "no hound in the country could throw a steer like this fellow does" (Carhart and Young 1929: 223). Caywood trapped Terror in the same area that Old Lefty had used. He recovered the skin and skull of the wolf, but we found no record of the skin or the skull in the Smithsonian Museum or other museums where specimens collected by Biological Survey personnel were deposited.

Greenhorn Wolf.

This female ranged the Butler Pasture country southeast of Pueblo, Colorado. The Greenhorn Wolf and her pack were responsible for losses of livestock worth thousands of dollars as well as numerous deer and Pronghorn Antelope (*Antilocapra americana*). By 1923 the Greenhorn Wolf's teeth were so worn that she was having difficulty killing prey (Young 1970). Young (1970: 279) termed her a "gummer" that had lived in the area for 18 years. Twice she had been in traps and a toe was missing from both front feet. She was killed about 25 December 1923 with strychnine poisoned ground meat that federal trapper Bill Caywood had placed to kill Magpies (*Pica pica*) (Young 1970: 294). Young (1970: 278) called her the "last native loner gray in Colorado."

Old Clubfoot.

This wolf became well known in the Escalante Hills in Moffatt County during 1906 and 1907. The name Old Clubfoot was given because the wolf lost two toes when he escaped from a trap and his track was easily recognized around kills. Old Clubfoot was killed on 7 June 1907 (Warren 1910: 94). D. M. Armstrong (personal communication, 7 April 1993), advised us that Warren's collection was at the University of Colorado Museum, Boulder, Colorado. We borrowed the skull of Old Clubfoot from the museum and used wear on the teeth and closure of sutures in the skull to estimate the age of the wolf (Landon et al. 1998) at 3 to 5 years at time of death. Thus, Old Clubfoot probably lived from about 1902 until 1907. E. R. Warren (1910: 94) indicated that

Old Clubfoot was particularly destructive and that cattlemen offered "an extra bounty for it (for the Wolf), in addition to those paid by the county and the cattlemen's association." J. Chew told Warren (1910: 94) that tracks of Old Clubfoot had been seen about the freshly killed carcasses of 75 cattle and horses, and that of these, he had personally lost 30 head. The tracks of other wolves were also observed around carcasses of livestock, but the fact that Old Clubfoot's tracks were always so much in evidence seemed to indicate that he was the "leading spirit" in the work. Chew indicated that after Old Clubfoot was killed no livestock were attacked on his ranch by wolves for more than two weeks.

Old Lefty of Burns Hole.

Old Lefty was credited with killing 384 head of livestock over an eight-year period, mostly in northern Eagle County. Old Lefty was caught in a trap in 1913 but escaped with a maimed or missing left foot. Young and Goldman (1944: 277) indicated that the "better part" of his left foot was lost in the trap; Carhart and Young (1929: 4,6) stated that the left foot was missing. According to Bennett (1994) the wolf was noted for his distinguishing gait. The wolf was trapped a second time in Eagle County, during the winter of 1920-1921. Biological Survey hunter Bert Hegewa trapped Old Lefty, then fitted him with a collar and chain, and staked the wolf out as bait to catch other members of the pack. During three nights, three pack members were trapped. Hegewa brought the hide and skull of Old Lefty, and a bottle of his scent, to S. P. Young in the Biological Survey headquarters in Denver, Colorado (Young 1970: 163-164). Young indicated that Old Lefty was ≥ 12 years old when he was killed and referred to him as a "gummer," but the teeth in photos of a mounted head labeled "Old Lefty of Burns Hole, Bureau of Sport Fisheries and Wildlife" on page 138 clearly show the skull in the mount was from a young wolf from 3 to 5 years-of-age. The fact that Young claimed the photo on page 138 was Old Lefty, and he made no mention of a substitute skull being used in the mount, casts doubt on the authenticity of Young's estimate of the age of this wolf.

Old Whitey of Bear Springs Mesa.

Old Whitey ranged over Bear Springs Mesa near Thatcher, Colorado for 15 years (Young 1970: 166-194). James Shaw, who raised cattle in the area, had known of this white male wolf frequenting his lands during the years 1909-1921. Young said this wolf was the mate of Three Toes of the Apishapa. One of Whitey's outstanding traits was bobtailing calves. He usually bit off the tails of calves as he came away from other kills which he had eaten. According to Young and Goldman (1944: 278), a study of several weeks duration indicated that "Old Whitey did the bobtailing for no other reason than sport." The wolf was apparently killed between 1921

and 1923. As Young started to trap for Old Whitey, he planned to use as bait scent taken from Old Lefty of Burns Hole when he was trapped by Bert Hegewa. The scent did not work and Old Whitey was finally trapped in a so-called blind set made by Young (Young 1970: 186). However, a man named Stoffel stole the Wolf out of Young's trap and claimed to have caught it in a trap set for Coyotes. Stoffel collected a \$25 reward and Old Whitey's skull and skin were observed by Young at Jonas Brothers Taxidermy Company in Denver, Colorado. Under pressure from Young, Stoffel finally wrote to Dr. Fisher of the Biological Survey confessing the theft and explaining how another man named Talbot helped him muzzle Old Whitey. Stoffel also wrote to Jonas Brothers and told them to turn the hide and skull over to Young.

Phantom Wolf of Big Salt Wash.

This female wolf ranged near Fruita, Colorado (Young and Goldman 1944). She commonly killed sheep and deer, and reportedly killed up to six yearling cattle in a single night, but would eat only a few strips of flesh (Young 1970: 261). Biological Survey hunter, W. J. Nearing, pursued the wolf from spring 1921 through 1923. During this time he claimed to have taken 21 of her pups. During the 1921 denning season Nearing found the Phantom Wolf's den; he placed a collar on one of her pups and staked the pup near the den. He then placed traps in a ring around the pup. The Phantom Wolf killed the pup during the night and avoided the traps. In spring 1922 Nearing shot, but did not kill, the Phantom Wolf. He trapped her mate and took six pups from their den. Nearing finally trapped and killed the Phantom Wolf in December 1923. Young (1970: 273) suggested that this wolf was part dog because her color was "tawny, almost like that of a collie." The likelihood of her being part dog was further supported because Nearing reported, when he examined her in December, that seven developing pups were in her uterus, indicating that she had mated at a date unusually early (i.e., wolves usually breed during January through March [Mech 1970]).

Rags the Digger.

This male wolf reportedly ranged around Cathedral Bluffs, southwest of Meeker, Colorado for 14 years (Carhart and Young 1929). The wolf mostly ranged alone, although he was sighted with two other wolves (Young 1970: 117). The date the wolf was killed is unknown, but it was probably between 1920 and 1924. Stockmen in the area claimed that this wolf had committed \$10 000 worth of damage. According to Young (1970: 112) the coat of this wolf always looked "ragged" and his back feet were larger than his front feet. Tracks of the larger rear feet were the identifying trait that allowed observers to say Rags had participated in a kill. When trapper Caywood caught the wolf, it pulled the drag on the

trap loose and fled. When Caywood caught up to the wolf, it turned and approached to within 2.4 m of Caywood with... "great, deep, low rumbling in (his) throat. His hair bristled, but it bristled as it might on the back of a dog, shy, beaten, crawling back to the feet of its master after it had done something wrong and by fawning sought forgiveness" (Young 1970: 133). The aforementioned characteristics suggest this wolf may have been a wolf \times dog hybrid.

Three Toes of the Apishapa.

Young and Goldman (1944) indicated that this female had been the mate of Old Whitey described above. She ranged with Whitey over the Bear Springs Mesa near Thatcher, Colorado, and northwest to the Apishapa River Valley. After Whitey and other members of the pack had been killed, Three Toes mated with a male collie and produced a hybrid litter (see photo of hybrid pup in Young 1970: 86). Three Toes and the collie killed a number of cattle on the Monroe Brothers and Henerson Ranch before the collie was killed with strychnine baits. Owners of the Monroe Brothers and Henerson ranch claimed Three Toes and her pack "killed thousands of dollars worth of calves and sheep. Just a few days prior to her capture, Three Toes killed six calves (on their ranch)." She was killed on 11 June 1923. Because she mated with a dog and repeatedly approached ranch houses even though ranchers were attempting to kill her, we suspect this wolf may have been a wolf \times dog hybrid.

UnawEEP Wolf, also called the Queen Wolf.

This female wolf ranged through the UnawEEP Canyon near Whitewater, and was named for the canyon (Young 1970). Her second name, Queen Wolf, came from having 12 wolves with her during the last two years of her life. When the wolves running with her were caught, there were eight of one size and four of another. Young (1970: 66) felt these were pups from her last two litters. Young and Goldman (1944: 283) reported that this wolf was killed in October 1921 and that the specimen was part of a group of mounted wolves in the Colorado Museum of Natural History in Denver. We were unable to locate a wolf skull in the museum identified as the UnawEEP Wolf or the Queen Wolf. However, we believe specimen ZM.1861 to be the UnawEEP Wolf: she was killed in 1921 and museum notes indicate that she was the adult female in a mounted group. We used wear on teeth and closure of sutures between skull bones to estimate the age (Landon et al. 1998) of this wolf at death at 6 to 8 years. This suggests the UnawEEP Wolf lived from about 1914 until 1921. Young (1970: 66) indicated that this wolf weighed 50 kg, was 193 cm in length, and had a remarkable shoulder height of 99 cm. UnawEEP's tracks were easily recognized because on her right front paw, the "middle toe was crossed" as a result of a trap injury some years before her final

capture (Young 1944: 283). Between 1 July and 1 October 1921, her kills reportedly included 19 yearling cattle and one 5-point deer; in addition a cow was mutilated by tearing off of the udder.

Connecticut

Unnamed female Wolf.

This is possibly the earliest description of a renegade wolf in North America. A female wolf and her pups ranged east of Hartford in the 1730s and killed large numbers of livestock at farms (Humphreys 1818, reproduced in Young 1946: 69–73). Each year the young were killed by hunters, but the old female could not be shot. When pursued, she would flee to the western forests and return the next winter with another litter of pups. The tracks of this wolf were easily recognized (especially in snow) because she had lost the toes from one foot when caught earlier in a steel trap. In 1739 General Israel Putnam operated a farm about 64 km east of Hartford (Young and Goldman 1944: 370–373). In one night 75 sheep and goats on his farm were killed and several lambs and kids were wounded by the female wolf. Hounds chased her to a cave, but no one would go in after the wolf. Finally, the General entered the cave using a torch for light and shot the wolf.

Kansas

Two Toes.

Two destructive male wolves known as Two Toes lived in southern Kansas during the 1880s. One of the wolves inhabited the rugged area along Crooked Creek, south of Meade to the Cimarron River. This wolf was well known in 1882 and 1883 because he was often sighted with a large black female wolf and part of one of his front feet had been lost in a trap and his tracks were easy to recognize (Chrisman 1961). This pair of wolves attacked calves, mature steers, cows and even range bulls, and mules. Often the flanks of cattle were torn open and intestines would drag behind the cattle until they died. Ranchers around Meade hired a Black hunter, Willis Peoples, to kill Two Toes. Peoples pursued the wolf for 25 days. Late on day 24 of the hunt Peoples came suddenly upon Two Toes at a calf kill. He pursued the wolf on horseback until nightfall. Early the next morning Peoples, mounted on a fast, fresh horse took up the trail and soon sighted the wolf. He shot the wolf and delivered it to officials in Meade. According to Chrisman (1961), the wolf measured 213 cm from tip of nose to tip of tail. The second wolf known as Two Toes damaged cattle from about 1880 until 1884 in the Gyp Hills north of Hardtner in southern Barber County, Kansas, near the Oklahoma border (Bennett 1994). The wolf was named Two Toes after he lost two toes in a steel trap. Cowboys found a den established by the wolf and his mate. The cowboys caught a pup at the den and staked it alive on a nearby mound to attract the adult wolves.

Twenty-four traps were placed around the mound. The next morning the male wolf was in one of the traps, but he jerked free as the men approached, leaving two toes in the trap. Yost said that the wolf "single handed" set cattlemen in the region back many thousands of dollars in the years that he ranged on their pastures. This is an interesting comment as Yost reported that Two Toes' mate was killed the same year that the wolf lost his toes, and that he found another mate the next year. Yost said, the third spring Two Toes had yet a third mate. Then, Two Toes moved to a new location west of Aetna in the southwest part of Barber County, and according to Yost, brought three females with him. This indicates that at least five wolves besides Two Toes were involved in depredations attributed to him. According to Yost (1970), the damage to mules and cattle west of Aetna became so serious that cowboys held a "drive" with more than 20 dogs that resulted in several badly chewed up dogs, but the wolf escaped. Two Toes was finally killed, after his shoulder was broken in a fight with a buck deer, when eight dogs caught up to him and fought with him until a hunter was able to shoot the wolf. Yost said a \$1000 reward had been offered for this wolf by a Texas cattleman's association and local ranchers. But the hunters that killed the wolf were unable to collect the reward because there was disagreement about the identity of the wolf and, apparently, the hunters made little effort to collect it.

Manitoba

Black Buffalo-runner.

An adult male which ranged around Carberry, Manitoba, starting in 1897-98 (Seton 1929: 314). He reportedly killed many sheep and calves, and purportedly spread terror among parents that had children going to school, but was never known to have threatened a person. Alexander Langmuir killed this wolf (Seton 1929: 314).

Winnipeg Wolf.

An adult male which reportedly weighed 47.3 kg (Seton 1929). Seton believed he observed this wolf from a train in March 1882. The wolf ranged around Winnipeg and along the Red River, and was killed near the Winnipeg slaughterhouse. The wolf was mounted by W. R. Hine, a taxidermist, and shown at the Chicago Exposition in 1893. The specimen was lost in the Mulvey Grammar School when the building was destroyed by fire in 1896 (Seton 1929: 313-314). Seton (1929: 314) admitted that he took "a writer's liberty" in telling the story of the Winnipeg Wolf and ascribed adventures to him that really belonged to other wolves.

Mexico

Las Margaritas.

According to Brown (1983: 159-163), R. T. McBride (1980) named this wolf and provided

details about it. The wolf had two toes missing from its left front foot. It ranged over a large area from the Zacatecas-Durango border through almost the entire state of Durango. The sex of the wolf is uncertain because Brown (1983) referred to it as "she," but a photo on page 160 in Brown (1983) labeled "Las Margaritas" clearly shows a penis on the dead wolf. McBride became familiar with this wolf while he was trapping in Durango for the Cattlemen's Union. McBride (1980) spent 11 months trying to trap the wolf. In spring 1970 Las Margaritas moved north to the Mazatlan-Durango Highway and began killing steers. Brown (1983: 161) noted that in April the wolf killed 13 steers, in May it killed more cattle, and during June it killed 18 steers. Periodic reports of this wolf killing cattle continued until McBride trapped it on 15 March 1971.

Old One Toe.

This wolf commonly crossed the border between Sonora and Arizona, and was well known for livestock depredations in both states. See the description of this wolf in the Arizona section.

Minnesota

Lobo Giant Killer Wolf of the North.

During 1926 this wolf and his unusually large tracks were first observed in Itasca State Park, Minnesota (Graham 1938), and for 12 years he ranged between Red Lake and Itasca. The wolf was never known to have a mate or to run with other wolves. According to Graham, Lobo killed more than 1200 deer valued at \$15 000 and other wild game, but he avoided livestock. A number of Game Wardens were assigned to kill the wolf and other experienced hunters also pursued him. Finally, Herman Gordon, a State Game Ranger, invited any trapper to try to take the wolf. J. Algot Wicken responded, and set wire snares for the wolf. The wolf was caught the second night, but he broke loose, with the snare still on his neck. Two years later Wicken caught the wolf in a steel trap. Examination of the carcass showed the snare that had caught the wolf earlier, had cut deeply into his neck, partially severing his trachea and retarding swallowing of food. Graham reported the wolf weighed 64 kg. This wolf has been on display as a mounted specimen in Bemidji, Minnesota, for many years. We purchased the lower jaws and teeth (now in possession of senior author) from the owner of the mounted specimen after it was refurbished and fitted with artificial teeth.

Montana

Big Timber Killer.

This wolf ranged north of Big Timber, Montana until he was killed in 1920. Killer was thought to be responsible for killing as many as 6 to 12 cattle on some nights, and reportedly killed at least 15 Shepherd dogs in two years (King 1965). Writer A. Funderburk published a detailed account of this wolf

in the Billings Gazette (9 February 1961). The wolf was known for killing Coyotes while they were caught in traps. Biological Survey hunter, B. M. Brannin, caught Killer by placing traps around a Coyote that was alive in a trap. Killer dragged his trap near the Coyote and killed it before Brannin ran the traps.

Old Crazy Mountain Wallis.

This wolf was part of a pack that ranged the Crazy Mountains region of Montana (King 1965). From Spring 1920 to fall of 1921 Old Wallis and a second wolf killed approximately 60 cattle. Old Wallis purportedly killed \$30 000 worth of livestock during a 14-year period. The wolf had the uncanny ability to split a dog pack by running between the dog pack and the other pursued wolves, and then howling, which confused the dogs. B. M. Brannin trapped Old Wallis in September 1921; pictures of this wolf and his capture are in King (1965: 100–101).

Old Snowdrift and his mate Lady Snowdrift.

Old Snowdrift was also known as the *White Wolf of Judith Basin*, *Ghost Wolf of the Littlebelts*, and *Old Snowslide* (Bennett 1994). Both Old Snowdrift and his mate, Lady Snowdrift, were white wolves that purportedly damaged livestock in the Judith Basin of central Montana during the 1920s (King 1965). During two months in 1922 the pair reportedly killed 21 cattle. A forest ranger trailed them to their den and captured seven pups. He trained one of the pups, known as Lady Silver, that appeared in Hollywood movies. Later in 1922, Lady Snowdrift was killed by a Biological Survey hunter. Old Snowdrift continued to inhabit the Judith Basin as a lone wolf until he was shot by A. E. Close on 8 May 1930. Close was paid a bounty of \$400. The wolf purportedly killed \$35 000 worth of livestock. According to King (1965) he weighed 38 kg and was believed to be 18 years old when killed. The wolf was mounted and is presently on display at a business in Stanford, Montana. The specimen is property of Judith Basin County (R. Cervenka, Chairman, Judith Basin County Commissioners, Stanford, Montana, personal communication). Detailed information about this wolf was provided by King (1965) and Bennett (1994), and in newspaper articles by Mary Lou Sennett (March 1993, *Lewiston News Argus*) and Eric Thane (12 April 1953, *Empire Section of the Denver Post*).

Snow Slide of the Highwood Mountains.

This was an old white male wolf that inhabited the Highwood Mountains of Montana (King 1965). During one night Snow Slide reportedly killed 16 sheep; a few nights later he killed 43 more. The following week the wolf reportedly killed 13 more sheep at another ranch. None of the sheep were fed upon. Snow Slide was poisoned by Biological Survey hunter, B. M. Brannin, on 4 March 1927

after a 10-month chase (King 1965). This may have been the last wolf killed by Biological Survey hunters in Montana.

White Wolf of Cheyenne, also known as *Buffalo Bill* and *Cody's Captive* (Seton 1929: 316).

This white male wolf was captured as a pup "on one of the far northern Montana ranges by Colonel Bill Cody (Buffalo Bill)" (see *Denver News*, 9 November 1899). Cody took the pup to his North Platte Ranch, but when the animal was one year-old it escaped and reportedly moved north to the Grover cattle ranges. The newspaper article referred to the wolf as "the great white marauder" and indicated he was "proving himself more savage and voracious than ever." Young and Goldman (1944: 276) mentioned this wolf and cited Seton (1929). This account has a number of points that are very similar to an account presented by Seton (1937: 1–26) about a large male wolf called the *Cody Wolf* and *Shishoka*, the *Red-head*. This wolf was the son of a white female called *Wosca*. We believe that Seton's (1937: 1–26) account about *Wosca* and her pup, the *Cody Wolf*, are based on earlier stories of the *White Wolf of Cheyenne* which Seton claimed to also be about a wolf that had been raised by Buffalo Bill Cody (Seton 1929: 316). According to Seton (1937) *Wosca* was a white female with a toe missing from each front foot and a "punched left ear". She ranged in the valley of the Little Missouri River, mostly in Butte County, Montana about 1890 (Seton 1937: 2–14). *Wosca's* pup, the *Cody Wolf*, was captured and raised by a wolf hunter named Bud Dalhousie. Buffalo Bill Cody bought the wolf and took it to his ranch on the North Platte River in Nebraska. The *Cody Wolf* was fitted with a collar so it could be chained. The wolf escaped and reportedly returned to Butte County, Montana, where it joined its mother, *Wosca*. The two wolves then ranged the border area between Montana and North Dakota damaging livestock for 10 years. *Wosca* disappeared, but the *Cody Wolf* reportedly continued to kill livestock. Apparently *Wosca* had aged and become weak. She was trapped in a depression called a "sink or volcanic blow-hole" for a lengthy period (Seton 1937: 22–24). While in the sink hole, she had water available in a depression and she depended on food brought to her by the *Cody Wolf*. At the lowest point, the steep bank around the sink hole was about 2 m high. This was the spot where the *Cody Wolf* would enter and leave. Bud Dalhousie observed the *Cody Wolf* carrying sheep to his trapped mother. Dalhousie trapped the *Cody Wolf* at the base of the low point in the bank, where he jumped into the sink hole to carry food to *Wosca*. Dalhousie shot both the *Cody Wolf* and *Wosca* when the *Cody Wolf* was trapped in the sink hole (Seton 1937: 25–26). The *Cody Wolf* was supposedly still wearing the collar placed on him at the Buffalo Bill Cody ranch.

New Mexico

Big Boy.

This was a male wolf that reportedly inhabited a range of about 31 km² in extreme eastern New Mexico between the Pecos River and the Texas border for five years (Graham 1938). A range rider observed this wolf and a second wolf traveling together early one morning. He shot the smaller wolf, an adult female, but the large wolf escaped. The ranch foreman named the large wolf "Big Boy". This wolf reportedly was easy to recognize by his large size and unusually light color. For three more years this wolf reportedly killed large steers and cows, but would not eat them; feeding mostly on calves and deer. A number of trappers and hunters using dogs tried to kill Big Boy, but were unsuccessful. Three years after the female wolf traveling with Big Boy was shot, a second female and one pup within his home range were killed by a rancher. Big boy reportedly raised the remaining pups and continued to kill livestock. Biological Survey trapper, J. Albert Pickens, trapped and killed Big Boy (Graham 1938), probably between 1919 and 1924 since Pickens started working for the Biological Survey in 1919 (Pickens 1980) and wolves were apparently eliminated in eastern New Mexico by 1924 (Brown 1983: 70). The foreman of the ranch where the wolf was killed gave Pickens a saddle horse as a reward. The Wolf weighed 36 kg and measured 74 cm at the shoulder.

Black Warrior.

This was a large black male that ranged over the Heart Bar Ranch near the head of the Gila River (Graham 1938). Losses of cattle to wolves on this ranch were heavy about 1920 and the foreman, Tom Perion, requested assistance from the U.S. Biological Survey. J. Albert Pickens, the renowned wolf trapper that had taken Big Boy in eastern New Mexico, was sent to kill the wolves (especially the black wolf) and Mountain Lions (*Puma concolor*) on the ranch. For two years Pickens hunted the predators and killed 8 wolves and 20 lions, but was unable to trap the black wolf. Losses to wolves continued on the Heart Bar Ranch and the following spring Pickens was again assigned to work there. While searching for sign in an area where the black wolf had been sighted, Pickens found a fresh killed calf from which about half the meat was gone. He suspected this meat had probably been taken to a wolf den to feed puppies. Pickens placed hounds on the trail and followed them to a den. Black Warrior became so involved in fighting the dogs that he was not aware of Pickens' approach. Pickens shot the black wolf, but the mother and puppies escaped. This wolf stood about 76 cm at the shoulder and measured 142 cm from nose to base of tail (probably about 178 cm to tip of tail).

El Comanche.

Graham (1938) described this wolf as a large white male that ranged along the Brazos River in Rio

Arriba County from about 1920 through 1926, and possibly for several years after 1926. This wolf and the pack he ran with reportedly caused serious losses of cattle on the Peterson and Braden Ranches. Biological Survey hunter, J. Albert Pickens, pursued El Comanche for three months in 1926 and trapped his mate and several members of the pack. On one occasion, Pickens trapped El Comanche, but the white wolf escaped, leaving part of a foot and toes in the trap. In September 1926, Pickens abandoned efforts to trap the wolf. Graham (1938) did not know the fate of this wolf, but ranchers reported seeing a large white wolf years after Pickens left the area. This was one of only three reports we encountered about a famous wolf that did not end in the death of the wolf; the other reports are Badlands Billy of North Dakota and the Yellow Hammer Wolf of Wyoming.

El Lobo Diablo.

A male wolf that reportedly caused serious damage to cattle from autumn 1915 through autumn 1918 in rugged areas of western Colfax and north-eastern Taos Counties, New Mexico (Graham 1938). During this three year-period the wolf and his tracks were always observed alone, even though other wolves were in the area. This was considered the most cruel and wary wolf in northeastern New Mexico. The wolf became famous in autumn 1915 when he reportedly killed 17 yearling cattle in a single night. According to Graham (1938), the A6 Cattle Ranch dehorned 1000 yearlings and turned them loose on the range. That night El Lobo followed the bleeding yearlings until he overtook them and killed 17 before morning. This is the largest number of cattle reportedly killed by a lone wolf during a single night that we found in our search of literature. Calves were favored as prey over older steers or cows. The wolf attacked calves by biting their rump and tearing away chunks of flesh without killing them. Often the wolf attacked the same calf several times, tearing out a chunk of tissue and eating it before he attacked again. The calves usually died later from infection and many were shot when discovered. Carbyn et al. (1993) noted that Bison calves that survived attacks by wolves sometimes developed blood poisoning from the bacteria, *Pasturella multocida*, found in the mouths of wolves. Graham indicated that in his 50 years of hunting and observing wolves, he had never known of another instance of a wolf taking a chunk of tissue from an animal, releasing the animal, eating the flesh, then repeating the attack again and again. However, recent observations of wolf attacks on Bison (Carbyn et al. 1993: 206–209) suggest that tearing issue from the rumps and flanks of Bison before they are killed may be common. Several well known trappers, including H. C. Gimson of Eagle Nest, New Mexico, tried to catch this wolf and

failed. The wolf was finally killed by Game Warden Arthur Black in the fall of 1918. Black was paid "several hundred dollars" bounty. The wolf weighed 39 kg and had unusually large shoulders and forelegs.

Lobo - The King of Currumpaw and his mate *Blanca*.

Lobo was a gray male and Blanca was white. These wolves were made famous by accounts presented by Ernest Thompson Seton (1898, 1913; Wiley 1954). Seton (1929: 314) admitted that he took a writer's liberty in telling some of the story of Lobo, but according to Seton the account of Lobo's capture and death "is given exactly as it happened." Lobo ranged the so-called Currumpaw region of New Mexico from 1889-1894. This wolf, his mate, and the pack they ran with were costly depredators on cattle and sheep. One night in November 1893, Blanca and another member of the pack killed 250 sheep and ate none of their flesh. Seton caught Blanca in a steel trap, and he and another cowboy each threw a lasso over the wolf and strained their horses in opposite directions until she was dead. Seton then set traps and dragged the body of Blanca over them to attract Lobo. That night Lobo was caught. Seton tied his feet and mouth, took him back to the ranch, and staked him out with a collar and chain. Seton indicated that the next morning he found the wolf dead. Lobo weighed 68 kg. The skulls of this wolf and its mate (Blanca) are in the National Museum of Canada, specimens number 1875 and 3726, respectively. The skin of Lobo is in the Philmont Museum at Cimarron, New Mexico, specimen number SET-L37.

North Dakota

Badlands Billy, also known as the *Big Dark Wolf of Sentinel Butte* and *Duskymane*.

This male wolf and his foster mother, known as the *Yellow Wolf*, were made famous by Seton (Wiley 1954: 319-343). Badlands Billy purportedly was born in 1892 and ranged the area around Sentinel Butte in western North Dakota. His foster mother was trapped and killed before he became an adult. Badlands Billy reportedly lived for a number of years (age not given) and killed numerous cattle and sheep. Seton's story ended when Badlands Billy killed 15 dogs that were pursuing him. According to Seton (Wiley 1954: 342) the wolf turned along a narrow mountain trail and killed the dogs as they came one or two at a time. The hunt for Badlands Billy was called off when the 15 dogs were killed. We suggest that this account may also contain some of Seton's fabrications that he called "a writer's liberty" (Seton 1929: 314).

Roosevelt Wolf, also called *Mountain Billy* and *Great Wolf*.

According to Seton (1929: 314-316), this wolf ranged near Medora, North Dakota around Sentinel

Butte from at least 1894 until 1902 when he was killed by G. W. Myers. Seton claimed to have hunted this wolf with members of the Eaton family in 1897. Later, Seton (1929: 315) indicated the wolf had lived in the area of Medora for 10 years and, in that time, had killed livestock worth many thousands of dollars. Seton (1929) quoted from a newspaper article (*St. Paul Dispatch*, 1 April 1902) that stated "the wolf had killed livestock worth an estimated \$5000". Mr. Myers had for years offered \$50 for the capture of the Roosevelt Wolf. Mr. Myers had intended to send the skin to President Roosevelt, but the skin was in bad condition, "not fit to be tanned." According to Mrs. Myers: "He was so old that his teeth were worn off almost to the roots" (Seton 1929: 314-316). The wolf reportedly weighed 76 kg and measured 239 cm from nose to tip of tail.

Oregon

Sycan Wolf of Southern Oregon.

Young (1944: 276) indicated that this wolf was old when finally captured near Fort Klamath, Oregon. It reportedly killed "many" horses and cattle over a period of 12 years (Young and Goldman 1944: 276, and Young 1970: 62).

Saskatchewan

Werewolf of Nut Lake.

This wolf of unknown sex was killed during March 1898 near Fort Qu'Appelle, Saskatchewan (Seton 1929: 314 cited Guernsey 1898: 460). It reportedly killed many cattle and ponies, and a five-year-old stallion weighing more than 546 kg.

South Dakota

Custer Wolf.

This almost white male was named the Custer Wolf because it ranged the vicinity of Custer, South Dakota, in the Black Hills region and into eastern Wyoming (Young 1970: 297). We estimated the age of the wolf at ≥ 10 years. Young (1970: 297) stated that the wolf had been known as an outlaw for nine years (Young 1970: 297) and it would have been at least one-year old before it started killing large numbers of livestock. According to Young (1970), the wolf killed livestock worth \$25 000 over a period of nine years. During this time the wolf escaped efforts by numerous sportsmen and stockmen to capture him, despite the offer of a \$500 bounty. The Custer Wolf's mate was killed in 1916 and it reportedly never took another. Young indicated that the wolf attached himself to two Coyotes that traveled far out on his flanks. The Coyotes reportedly were allowed to feed from the Custer Wolf's kills only after he had finished eating. The Biological Survey hunter that trapped the wolf, H. P. Williams, wrote that he was ... "smaller than the average male wolf, weighed 98 pounds (45 kg) and measured just 72 inches (183 cm) feet from tip to tip, eleven inches from toe to hock, and had a tail 14 inches long"

(Young 1970: 301). When Williams first saw the wolf on 1 April 1920 he wrote ... "The Coyotes were acting as body guards, traveling from 100 (91 m) to 200 yards (183 m) on the flanks of their master. They would warn him of danger by taking flight" (Young 1970: 301). Williams shot the Coyotes, and on 26 April, he noticed that the wolf was "...playing hide and seek with him. After making a kill, he would go some distance, back trail for a few rods to a point where he could keep under cover and watch the hunter on his trail" (Young 1970: 301). Government hunter H. P. Williams worked to capture the wolf from March to October 1920. He trapped the wolf on 11 October 1920. It broke the swivel on the trap and fled with the trap on its foot. Williams trailed the wolf for 4.8 km and shot it. Bell (1921) gave details of the life and death of the Custer Wolf.

Three Toes of Harding County.

Lopez (1978: 192) described Three Toes of Harding County as the most famous of the "outlaw wolves." This adult male was captured on 23 July 1925 about 20 miles northwest of Buffalo, South Dakota between Gallup and Dry House Creeks in one of 14 traps set to catch him by Biological Survey hunter C. R. Briggs (Young and Goldman 1944: 277). Over and Churchill (1941) felt that Three Toes was the last wolf in South Dakota. Young (1970: 63–64) reported that at least 150 men had attempted to kill this wolf during the 13 years it had been known as a killer in Harding County. He also noted that Three Toes destroyed 66 sheep belonging to one ranchman in two nights. Over and Churchill (1941: 20–21) said this wolf killed livestock in northwestern South Dakota for at least 14 years. They reported three occasions when during a single night this wolf killed large numbers of sheep: 34, 17, 28. Stockmen asserted that Three Toes killed livestock worth more than \$50 000. The skull of this wolf is in the Smithsonian Museum, specimen number 2224.

White Wolf of Pine Ridge.

This white female occupied an area 24 km across between Pine Ridge and the Badlands from 1899 until 1912 when she was finally killed by wolf trappers (Seton 1929: 314). She was once observed with seven pups. One pup was caught and staked out for a decoy. But the White Wolf came at night, eluded the watchers, pulled up the stake, and carried off her pup. Wolves in this area were so troublesome that a \$25 bounty was paid for each scalp, but double that was offered for the scalp of the White Wolf (Seton 1929: 314).

Texas

White Lobo.

According to Brown (1983: 163–165) this white female, was the "...last one (wolf) in Texas." Williams (1974) interviewed M. Wallace to deter-

mine how he killed White Lobo. Wallace trapped for this white wolf from 1920 through 1924 after A. M. Cone indicated he would pay \$500 to anybody who killed the wolf. Wallace finally shot the wolf in 1925. He said the wolf was deaf and had no sense of smell because a year before he killed her, she had crossed a road about 25 steps ahead of him. Wallace traveled "noisily along on horse back at least 25 steps before the wolf saw him." Also, the day he killed the wolf, he and another rider had passed on horseback on three sides of the wolf without it being aware of them. According to Wallace "She was a fairly old female, all snow white, except a gray-tipped tail. She couldn't hear or smell, that's why I hadn't been able to catch her with scented and baited traps."

Wisconsin

Old Two Toes of Bayfield County.

This male Gray Wolf ranged isolated sections of Bayfield County (Thiel 1993). No damage was attributed to this wolf. He had been a loner since at least 1954, when other members of his pack had been killed. Only a few wolves survived to the end of the bounty era in Wisconsin. This wolf was hit by an automobile, beat with a tire iron and had his throat cut in January 1958 (Thiel 1993). His skull, skeleton, and hide are at the University of Wisconsin Zoology Museum (specimen number UWZ-15213).

Old Two Toes of Oneida and Price Counties.

This wolf was not reported as a damaging wolf, but it was one the few well known wolves from Wisconsin. He was identified by his peculiar tracks from at least 1945 to 1949, when he was finally trapped and killed (Thiel 1993). This wolf was part of the Willow Pack, a pack of wolves studied by biologists from the Wisconsin Conservation Department (Thompson 1950, 1952). Thompson felt the old wolf was not able to keep up with his pack-mates. "He was evidently handicapped under these particular snow conditions for his maimed pads would frequently break through the light crust. The three wolves accompanying him trotted along easily on the surface of the snow." Trapper Walt Rosenlaf considered Old Two Toes to be the alpha male of the Willow Pack. From 1945 to 1949 he reportedly ranged an area of about 114 km², considerably smaller than the 324–389 km² range reported for the rest of the pack.

Unnamed Female Wolf.

During December 1946 and January 1947 a female wolf apparently attempted to mate with dogs on two occasions before she was killed by their owner (Thiel 1993: 28–30). The only damage reported for this wolf was "courting dogs". The female wolf apparently courted a Chow-mongrel dog on the Ernest Anderson farm near Skunk Lake, Oneida County, Wisconsin. The same wolf was seen nearby

at the Herman Witt residence "acting friendly with their dog" early in the morning two days before she was killed. Biologist Dan Thompson investigated the incident and stated the wolf was thought to have been raiding garbage dumps in the Skunk Lake area just north and east of the Willow Pack's territory. She was old (based on tooth wear), but in excellent condition (Theil 1993).

Wyoming

Bob Drew Wolf.

In 1919 a trapper named Bob Drew captured 13 pups from a wolf den south of the C. B. & Q. Railroad track between Sheridan, Wyoming, and Edgemonth, South Dakota (King 1965). He also killed two adult females that were sharing the den. Ranchers in the area were paying bounty on wolves killed south of the railroad track. Drew presented the wolves for bounty payment, but the bounty clerk claimed that the wolves were taken north of the railroad track and payment was refused. Drew was angry and he took the pups back to their den, cut their tails off, and turned them loose. At the time the pups were several months old and able to care for themselves. Most of the pups reportedly survived and established ranges around Gillette. The last of these bobtailed wolves was caught in 1924 and it was known as the Bob Drew Wolf. The 13 bobtailed wolves cost livestock producers in the Gillette area an estimated \$100 000 in damages (King 1965).

Custer Wolf.

Part of this wolf's range was in extreme eastern Wyoming and part was in western South Dakota. The Custer Wolf was well known in both states. See the description of this wolf in the South Dakota section of this paper.

Old Angora.

Day and Nelson (1928) indicated that this unusually large white male wolf inhabited the Jackson Hole area. This wolf had a long record of killing livestock and big game. According to Day and Nelson (1928), Old Angora was probably the oldest wolf ever taken in Wyoming. Day and Nelson (1928) noted that his teeth were worn almost to the gums. An estimate of age was not given, but the description suggests the wolf probably was at least 14 years old. The wolf received his name because he was white and his long hair resembled hair of an angora goat suggesting that he was probably a wolf \times dog hybrid. He was killed before 1928.

Three Toes, also known as the \$10 000 Split Rock Wolf.

This was an old female wolf that ranged the area around Split Rock, Wyoming during the early 1920s and, according to Day and Nelson (1928), killed at least 50 cattle annually. The tracks of this wolf were reportedly easy to recognize during the last year of her life because one toe was lost when she was

caught and escaped from a trap set by a Biological Survey hunter. The following year a second Biological Survey hunter trapped and killed the wolf. Day and Nelson indicated that in the interval between the two trappings Three Toes killed about 200 cattle plus unknown numbers of deer and Pronghorn Antelope. The names Three Toes and \$10 000 Split Rock Wolf came from the loss of one toe and the value that ranchers placed on livestock that the wolf reportedly killed, respectively.

Unnamed Large Wolf.

This gray male was the largest wolf anyone in the vicinity of Mayoworth, Wyoming, had ever seen, according to J. E. Brock, secretary-treasurer of a Wyoming bounty association that paid bounty on hundreds of wolves (King 1965). The wolf reportedly was well known because of his remarkable size and his extreme cunning. He reportedly killed both cattle and horses, but preferred horses and could kill grown ones easily. The tracks of this wolf were easily recognized because they dwarfed other Wolf tracks. This male denned each spring near Mayoworth and he usually had two mates and maintained two dens. Mr. Brock pursued the wolf from 1905 until 1910; in December 1910 Brock shot the wolf from horseback while following him. The pelt of this wolf is shown on page 128 of King (1965) and it was placed in the Johnson County Jim Gatchell Memorial Museum in Buffalo, Wyoming.

Unnamed White Wolf.

Wilson (1985) stated that he killed the last wolf, or one of the last wolves, in Wyoming on the day after Thanksgiving in 1949. This large white male wolf had been sighted several times in Fremont County during the summer of 1949. The wolf reportedly killed over \$10 000 worth of sheep belonging to one rancher during summer and fall, 1949. Wilson was a trapper for the U.S. Fish and Wildlife Service and he felt confident that the sheep were being killed by an old dog with few teeth. The sheep were always attacked from the rear, with lots of wool pulled out, flanks torn open, and entrails pulled out. Usually the liver was eaten. Wilson became convinced that a large watch dog that belonged to the sheep rancher's neighbor was attacking the sheep. Wilson killed the dog, but the sheep losses continued. Wilson then poisoned the wolf with a cyanide gun set near the sheep corrals and losses stopped. Bennett (1994) indicated the wolf was very old with only five worn teeth remaining in his jaws. We believe such a wolf could be ≥ 14 years old.

Yellow Hammer Wolf.

This male wolf was thought to be the last wolf in the Gillette area; he reportedly caused serious damage to livestock in the Rochelle Hills and along Yellow Hammer Creek, Wyoming (King 1965). In 1925 this wolf reportedly killed 35 sheep one night

on the T-7 Ranch. After the sheep were killed, the Yellow Hammer Wolf was hunted so hard that he left the area and no signs of the wolf were seen again. This is one of only three accounts of famous wolves that did not end in the death of the wolf (see El Comanche in the New Mexico section and Badlands Billy in the North Dakota section).

Discussion

Several factors have contributed to the general acceptance of accounts of famous damaging wolves in North America. The accounts were published in the late 1800s and early 1900s during the period when the founding literature for Wildlife Management as a scientific discipline was being published. Many of the accounts were written by respected naturalists (including Ernest Thompson Seton, Stanley P. Young, and Gid Graham) and early wildlife scientists may have been hesitant to challenge their work. By the time objective studies of wolf predation started to be published in the 1940s (Murie 1944) and 1950s (Thompson 1952; Burkholder 1959), wolves were already extirpated from most areas where the famous wolves had occurred and there was no obvious way to validate early reports.

The livestock industry also changed early this century. Longhorn cattle and Longhorn crosses were the dominant breed in western states before World War I, but by 1927 they had been almost totally replaced by Herefords, Angus, and other improved breeds (Barnes 1928). Longhorns were known for their aggressiveness toward predators and their defense of calves (Dobie 1941: 18–20, 161–168; McIntyre 1995: 75–78), while improved breeds were highly vulnerable to large predators (Gish 1978: 48, 86). Longhorns matured slower than modern breeds, not reaching maximum weight until eight or ten years old. Longhorn steers were not considered mature and ready to market until past four years, while Herefords were commonly sent to market as two years olds (Dobie 1941).

Some of the accounts of famous wolves were exaggerated and inaccurate. Accounts by two writers are particularly important: Ernest Thompson Seton and Stanley P. Young. These authors presented some of the first and most widely read accounts of notorious wolves. Their writings about wolves influenced generations of wildlife biologists and millions of people throughout the world.

Ernest Thompson Seton (1898, 1929, 1937; Wiley 1954), a noted naturalist and popular writer of the late 1800s and first half of the 1900s, stands out among the writers of famous wolves because he often prefaced his accounts with explanations of their validity and extent of embellishment. For example, Seton (1937: viii–ix) stated that his account of Wosca and the Cody Wolf (see White Wolf of

Cheyenne in the Montana section above), was based on “well-authenticated incidents” and his personal experiences while hunting the Cody Wolf near Medora, North Dakota. He acknowledged that episodes of more than one wolf were “compounded” in the Cody Wolf. Seton also admitted that he took a “writer’s liberty” in telling some of the story of The Winnipeg Wolf. But in writing about Lobo - The King of Currumpaw (see New Mexico section above), Seton (1898: 10) stated that their was “almost no deviation from the truth” and that Lobo “died, precisely as related.” Seton said that the morning after he trapped Lobo and secured him with a collar and a strong chain, he found the wolf dead, “his body unwounded.” However, we examined the skull supposedly from this wolf and found an unhealed gunshot wound between and above the eye sockets suggesting the wolf died from a gunshot. Either the skull we examined was not that of Lobo (the label on the skull, however, appears to be in Seton’s handwriting) or Seton’s account of the death of the wolf was wrong. Seton also claimed that Lobo stood three feet at the shoulder (91 cm) and weighed 150 pounds (68 kg). Gish (1978) reviewed the weights of numerous wolves from New Mexico and concluded that it was unlikely that Lobo actually weighed 68 kg. The largest wolf from New Mexico that Gish described weighed 57 kg.

Stanley P. Young was a prolific writer and highly influential in determining Federal and State policies regarding the management of wolves and other predatory animals. Young was hired as a predatory animal hunter by the U. S. Biological Survey in 1917. He quickly progressed to supervisor of predatory animal work in Colorado and Kansas. In 1927 he was assigned to Washington, D.C., and progressed to become Director of the Department of Interior Bird and Mammal Laboratories. During the early 1920s Young collected reports about damaging wolves from Biological Survey hunters and newspaper stories (see *Denver Post* issues for 21 November 1922, 6 July and 18 December 1923; *Rocky Mountain News* 10 April 1921; *Daily News* 14 October 1922). In 1928 and 1929 Young collaborated with A. H. Carhart to write stories about eight renegade wolves for *Red Book* and *Blue Book* magazines. These accounts, and an additional story of a notorious wolf, were then published in 1929 in a widely read book titled *The Last Stand of the Pack*. Young testified about damaging wolves and other predators at United States Congressional hearings in support of the 1931 Animal Damage Control Act (U. S. House Committee on Agriculture 1930, U. S. Senate Committee on Agriculture and Forestry 1931). Young’s accounts of famous wolves were assured a place in the scientific literature when he and co-author E. A. Goldman included them in *The Wolves of North America* (Young and Goldman

1944: 275–285) published by the American Wildlife Institute. This remained probably the most widely cited reference book about wolves until Mech published *The Wolf* in 1970. Just before his death in 1969, Young repeated eight of the accounts in his last book, *The Last of the Loners* (Young 1970).

The accounts of famous wolves that Young presented contributed to the belief that wolves are beasts of destruction that must be controlled to benefit livestock and wildlife. Even in his last book, Young (1970) failed to acknowledge that his accounts were speculative and that many details were fabricated. One of the obvious problems with Young's accounts of famous wolves was the unreasonably old ages he assigned to the wolves. He gave detailed information for 11 notorious wolves and seven of them were ≥ 10 years old: five of the seven were ≥ 14 years of age; Big Foot (see Colorado section) was 17 years old and the Greenhorn Wolf (see Colorado section) was an almost unbelievable 18 years old when killed. Current literature suggests that wild wolves rarely live to be 12 years old. Ballard (1993) captured and radio-collared 86 wolves in northwestern Alaska and only three of these wolves lived to be more than nine years old. Two lived to between 9 and 10 years; one of these was alive when last located in 1991 (Ballard 1993). A third wolf lived to be over 14 years old. Records from Mech (1988) indicated that wild wolves in Minnesota may reach 13 years.

At least one of the wolves that Young described, Old Three Toes of Harding County, South Dakota (see South Dakota section above), did not appear to have been from South Dakota as reported by Young and Goldman (1944: 277) and Young (1970: 63–64). When the first author examined the skull of Old Three Toes in the Smithsonian Museum (specimen number 2224) it was markedly larger, with much larger teeth, than skulls of other wolves from South Dakota. We suspected that the wolf was not from South Dakota. This suspicion was supported independently by Nowak's (1995) multi-variate analysis that demonstrated the wolf was similar to wolves from much farther north in Canada. The Biological Survey hunter, C. F. Briggs, who killed Three Toes, spent only 15 days on this job and caught the wolf in the first of 14 traps that he set (Smithsonian Institution Archives. Undated. Smithsonian Institution Manuscript Collections, Stanley Paul Young papers, 1921–1965. Record unit number 7174, box 9, folder 3. Washington, D. C.). This was an extraordinary accomplishment considering that reportedly "150 men had attempted to take the wolf during the 13 years that it had been known as a killer in Harding County" (Young and Goldman 1944). Mr. Briggs received national recognition for killing Three Toes, he was also awarded an engraved gold watch, and soon after taking the wolf he was promot-

ed to head the predatory animal control program in Arkansas. The physical features of this wolf and the circumstances related to its capture lead us to suspect fraud, where the carcass of a large wolf with three toes might have been brought to South Dakota and presented as Three Toes.

There is also confusion about the identity of another notorious wolf, Old Whitey of Bear Springs Mesa (see Colorado section), described by Young (1970: 166–194). Young (1970: 176) published a photograph of a wolf titled "Old Whitey of Bear Springs Mesa" that he stated was from Colorado and that had been the mate of Three Toes of the Apishapa. This is the same photograph that appeared 42 years earlier in Day and Nelson's (1928: 7) publication about wildlife damage control in Wyoming with the heading "Old Three Toes, notorious Split Rock Wolf, trapped in 1920."

Undoubtedly some accounts of famous damaging wolves were accurate (cf Mech 1970), but determining which accounts are accurate requires scrutiny in light of recent discoveries concerning wolf: prey relationships and wolf population dynamics (Fritts 1982; Fritts et al. 1992; Gasaway et al. 1983, 1992; Bjorge and Gunson 1983, 1985; Ballard et al. 1987, 1997; Fuller 1989). Elaborations by Seton (1929) indicate that details of at least some accounts were fabricated. Most reports of damage from famous wolves were based on personal interviews with livestock producers and professional hunters/trappers hired to kill predators. A number of critics of wildlife damage control contend that livestock producers over-state predator losses to shift blame of the loss from poor management practices, or to gain more intensive predator control. This allegation was examined, but not proven, during an extensive study of predator damage in western states (Fish and Wildlife Service 1978). Wagner (1988) compared results of studies of livestock losses to predators based on interviews with livestock producers and results of intensive field studies by professional study teams. In most cases the results of interviews paralleled those of the field studies.

Reported rates of predation by famous wolves are especially interesting. Some are unequaled in terms of the magnitude of losses reported. Young and Goldman (1944) indicated that Three Toes of Harding County in South Dakota killed livestock worth more than \$50 000 over a 13-year period ending in 1925 (Young 1970). The average value per head of cattle in South Dakota in 1925 was \$30.60 (Crawford 1928). Expressing the wolf's kill in terms of cattle, would translate to about 1634 cattle killed in 13 years, roughly 125 per year or one about every three days. The Custer Wolf, also from South Dakota, reportedly killed livestock worth \$25000 over a nine-year period ending in 1920. Again expressing the kill in terms of cattle, the total would

be about 817 head, or roughly 91 per year or one about every four days. One explanation for the high kill rates is that much of the purported damage may have occurred from packs rather than individual Wolves. Fifty of 59 famous wolves purportedly killed large numbers of livestock. However, 29 of the 59 reports appeared to have been caused by ≥ 2 wolves (e.g. packs) rather than individual wolves.

Reports of surplus killing are also interesting and few events were noted that might have contributed to unusually high kills. Seton (1898: 20) reported that in New Mexico, Blanca and a second wolf killed 250 sheep in a single night and ate none of the flesh. An account written in 1818 (cited in Young 1946: 69-72) told of a female wolf in Connecticut that killed 75 sheep and goats in one night. In Arizona, the Aguila Wolf purportedly killed 66 sheep one night and 40 on another occasion (Brown 1983), and in South Dakota, Three Toes of Harding County killed 66 sheep in two nights (Young and Goldman 1944: 277).

In some cases, circumstances were noted that may have contributed to surplus killing. For example, the highest reported kill of cattle by a single wolf during one night occurred during fall 1915 in New Mexico when El Lobo Diablo killed 17 cattle between one and two years-of-age (Graham 1938: 63). The cattle were released onto a remote pasture after being dehorned, all of the cattle were bleeding from the dehorning operation, and the ability of the cattle to defend themselves was impaired by the loss of their horns. Graham believed that El Lobo Diablo was alone when he killed the cattle because signs showed that a lone wolf pursued the fleeing yearlings, killing one after another.

A number of famous wolves interacted with dogs. Two wolves were known for killing dogs; Big Timber Killer (see Montana section) reportedly killed 15 Shepherd dogs over two years along with a number of Coyotes (King 1965), and according to Seton (Wiley 1954: 336-343), Badlands Billy (see North Dakota section) killed 15 dogs in a single encounter while they were pursuing him along a narrow mountain trail. Five famous wolves were observed playing with dogs and three females courted male dogs: Three Toes of the Apishapa (see Colorado section), Ghost (see Montana section), and an unnamed wolf in Wisconsin. Three Toes actually produced a litter of five hybrids after she mated with a collie ranch dog (Young and Goldman 1944: 203-206).

Physical traits and behavior of seven famous wolves suggested that they might have been hybrids with dogs. Four of the possible hybrids were from Colorado including Rags the Digger, Phantom, Gray Terror, and Unaweep. Two possible hybrids were from Wyoming including Old Angora and Red Flash (Table 1), and one, the Custer Wolf, was from South

Dakota. The Unaweep Wolf is particularly interesting because of the unusual body measurements reported for the wolf by Young and Goldman (1944: 283): weight 50 kg, total length 193 cm, shoulder height 99 cm. If the shoulder height was correct, the body configuration of this wolf would have been remarkable, with the shoulder height to total length ratio being markedly larger than we found for other wolves (0.51 for Unaweep vs 0.46 to 0.47 for other wolves). We feel the reported shoulder height was probably an error. The shoulder height reported (Young and Goldman 1944: 446) for a Montana Wolf similar in size to the Unaweep Wolf was 84 cm (the Wolf weighed 48 kg and had a total length of 183 cm). Shoulder height for a larger Wolf from Wyoming (Young and Goldman 1944: 443) was only 94 cm (total length of this Wolf was 198 cm).

The color of wolves in North America is predominantly gray, although a range of shades from white to cream-colored, reddish, and black have been reported (Mech 1970). Thirty-nine famous wolves were gray, 16 were white or near white, and two were black. Two of the wolves were unusually colored: Red Flash of Wyoming (Day and Nelson 1928), had "glossy red-tipped fur" and the Phantom Wolf of Colorado, was tawny like a collie dog. As noted above, we suspect the last two were hybrids with dogs.

Only three accounts of famous wolves ended without the wolf dying: Badlands Billy of North Dakota, El Comanche of New Mexico, and the Yellow Hammer Wolf of Wyoming. Also, only three wolves (all from Wisconsin) became famous for reasons other than damage to livestock or game animals. Wisconsin wolf researchers (Thiel 1993; Thompson 1950, 1952) reported the movements of Old Two Toes of Oneida and Price Counties as part of studies of movements in the 1940s and 1950s, Old Two Toes of Bayfield County was thought to be the last wolf in Wisconsin, and an unnamed female became famous for courting dogs during 1946 and 1947.

Accounts of famous wolves are an important part of American literature, reflecting the pioneering culture of the late 1800s and early 1900s. Brown (1983: 155) referred to these accounts as "campfire legends" that tended to grow with each telling. We agree that parts of some accounts of famous wolves that made their way into the scientific literature were fabricated and represent what Romesburg (1981) called "unreliable knowledge". In other cases, the reports appear to be basically accurate and provide insight into what the last native wolves in western states were like. Most of these wolves were isolated individuals, physically impaired by old age and/or mutilated feet from being in traps. Accounts of famous wolves indicated that 19 were ≥ 10 years old, 18 had mutilated or missing feet from past trap injuries, and Lobo Giant Killer Wolf of the North

(see Minnesota section), had a partially severed trachea from being in a snare. Great caution should be used when referring to these accounts when used as a basis for wolf management decisions, or to predict likely predation rates when wolves are being considered for reintroduction.

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Book Reviews

ZOOLOGY

A Guide to the Identification and Natural History of the Sparrows of the United States and Canada

By James D. Rising. 1997. Academic Press, San Diego, California. 165 pp., illus. \$19.95.

I bought a copy of *Seabirds — an identification guide* (by Peter Harrison, Houghton Mifflin Company, Boston) as soon as I could. For me it was a wonderful, fresh book that filled an immediate need. In the fifteen years since that book was published, many other authors copied Harrison's style and produced books on ducks, crows, chickadees, and so on. All were good and were great additions to the birding library. *Sparrows* is, however, the first since seabirds that excites me because it fills a real need. All birders must at some point deal with identifying those mischievous "Little Brown Jobs" or LBJs. Even if you ignore them for most of the year, you are honour bound to make a positive identification for the Christmas bird count!

This book covers the currently accepted 62 species of North American LBJs (towhees, sparrows, juncos, longspurs, and buntings). It also includes the field-identifiable colour variations and forms, so the book will continue to be valid if the AOU makes further splits (or lumps). The author has also added Worthen's Sparrow, a strictly Mexican species that was separated from the Field Sparrow not long ago. The text covers identification, voice, habitat, habits, breeding, range, history, geographic variation, and measurements. Information under "Identification" delineates the adult summer and winter plumages, plus that of the juvenile; similar species are described for comparison. The text on "Range" is supplemented by a range map (and on occasions by a BBS map from *The Summer Atlas of North American Birds* by Jeff Price, Sam Droege, and Amy Price, Academic Press, San Diego, California).

There are 27 full-colour plates showing the various plumage variations between sexes, ages, and regions, plus additional details such as tail patterns. The illustrations are by David Beadle and are typical of this man's style. He captures the characteristic stance, proportions, and demeanour of his subjects really well. Then he adds some very exact feather

detail to provide an accurate portrait of each species. The author anticipates that some species, such as the Fox Sparrow will be split in the future so Beadle has also illustrated all the plumage variations. I suspect he has not seen an "Ipswich" Sparrow, however, as his illustration is a little too dumpy and short-tailed and maybe a trifle too small.

Naturally the author includes the recent splits like that of the sharp-tailed sparrows. After years of watching east coast sharp-tails I moved out west. I immediately had problems with the local, western sharp-tails. They did not sound right, look right nor behave quite the same as I expected. Shortly after my arrival the AOU split these sparrows into two. Rising's book covers this separation very well. I even see the difference in his description of the songs (ts-ts-sssss-tsik for Saltmarsh vs. pschee-zipt for Nelson's). Normally I find these written interpretations of song are not helpful as they rarely match the way I describe a bird's song. For example the author's tzip-tzip-ztreeeeeeeee-ip (Savannah) and chip-chip-scheeeeeeeeeeee (Grasshopper) does not really fit my mental image of these songs. The book also covers and illustrates the juvenile and immature plumages of the Clay-colored Sparrow. The speckled belly off the short-lived juvenile plumage has caught me of guard a few times.

Not surprisingly, I think this is an essential purchase for every North American birder worth his or her salt. There is no longer any excuse for not trying to sort out LBJs. Anyone who does so will find them as fascinating as any of their more readily identifiable cousins. This book will be an invaluable asset. I foresee myself consulting it often, particularly in the fall when the young sparrows provide an extra, difficult challenge. My advice is not to wait for someone to give this book as a gift; buy it now! You deserve it and need it.

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Handbuch der Vögel Mitteleuropas. Passeriformes, Part 5. Volume 14.

Tome 1: Passeridae to Vireonidae (pp. 1–303). Tome 2: Fringillidae to Parulidae

(pp. 313–1242). Tome 3: Emberizidae to Icteridae (pp. 1251–1966).

List of corrigenda and addenda for previous volumes.

Under the direction of Urs N. Glutz von Blotzheim. Edited by Urs N. Glutz von Blotzheim and Kurt M. Bauer. 1997. Aula-Verlag, Wiesbaden, Germany. 1966 pp. illus. 684.00 DM.

This volume concludes an impressive series that has become a classic and an unavoidable source of information on birds. It deals in details with the species that occur regularly in central Europe, as well as the accidental and vagrant species. Volume 14 consists of three tomes which total 1966 pages packed with high quality current information. The large size of the volume seems to be the main reason why it has been separated into three different tomes. Otherwise, the large size of a single book may have jeopardised the durability of the work. It is easy to find the species in spite of the split of the last Passeriformes families into the three different books. Families have been grouped in a convenient arrangement following modern classification principles. The quality of the production is excellent and the high standards established in the previous volumes are maintained; it would a great challenge for any publisher to surpass it.

This volume follows the organisational pattern adopted in the earlier volumes (see review of Volume 9, H. Ouellet. 1983. *Canadian Field-Naturalist* 97: 358). Jürgen Haffer is responsible for the systematic and classification aspects of this volume. All recent, and not so recent, sources have been solicited. The final results include information from many of these sources and are the basis for a classification that is different from recent proposals but that everyone familiar with avian systematics should find original and exciting. The details given in the introduction of each family are extensive and provide a good summary of the familial characteristics based on the most recent references. A key to the genera follows. Similarly, each genus is introduced by a lengthy summary that includes zoogeographic information and maps, in addition to the anatomical, eco-

logical, and behavioural material. A key to species comes next. Each species is treated in great detail and the information is based on the most recent sources. For example, the House Sparrow (*Passer domesticus*) dealt with in Tome 1 runs from page 46 to page 125. The sources of information are cited in an extensive 'Literatur' section of seven pages. No stone has been left unturned. This approach is maintained throughout the three tomes; as an additional example, the Ortolan (*Emberiza hortulana*) occupies more than sixty pages in Tome 3. Species that have been reported in Europe on an accidental basis, such as the Black-throated Green Warbler (*Dendroica virens*) receive the same generous treatment, including the familial and generic introductions. This wood-warbler, an accidental vagrant in Europe, is thus treated in great details and occupies more than eleven pages which contain even a detailed distribution map indicating the breeding and winter ranges.

This last volume is the best of an already excellent series. There is no doubt that the *Handbuch der Vögel Mitteleuropas* surpasses in quality and scope all other handbooks. This volume, and all the others of the series, should figure prominently in all major ornithological libraries. North American ornithologists should refer to it when dealing with the North American species included in it (there are many), even if it means to labour through the German text or obtaining translations of the pertinent sections. This is a work of very high standards and of the highest quality. It is solidly bound and attractively, but simply, presented. Its high price should not be a deterrent to its acquisition, at least for important ornithological libraries, because it will constitute a fundamental ornithological reference for many years to come. The editors, authors, and all those associated with its production should be proud of their accomplishment.

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Hybrid Ducks, a Contribution Towards an Inventory

By Eric and Barry Gillham. 1996. Privately published. Available from B. L. Gillham, P.O. Box 563, Wallington, Surrey SM6 9DX, U. K. 104 pp., illus. £16.00.

Since the publication of A. P. Gray's classic work on bird hybrids in 1958 [*Bird Hybrids. A check-list with bibliography*. 1958. Commonwealth Agricultural Bureaux, Farnham Royal, Bucks.], it was necessary to search an extensive literature to obtain information on hybrid ducks published after 1958. This time consum-

ing task required much effort because of the abundance of publications on the subject scattered in numerous international journals and publications, sometimes in difficult to find documents.

This small book provides the information currently available on 166 known hybrid ducks, 250 "crosses", and other combinations. The material has been compiled from the literature and is based also on the authors' collection of live hybrid ducks. Each entry

gives a "category" classification of the hybrid as defined by the authors and based on the progeny of the individual. It lists the number of known records and includes detailed descriptions of the hybrids, along with appropriate references. Many descriptions are based on observations of live birds by the authors or summarised from published material. Sixteen colour plates, showing 110 hybrids accompany the text and are a welcome extension to the written descriptions. They show live hybrids and museum specimens in various plumages, and are of excellent quality.

The compilation and the "selective bibliography" of over 225 titles appears to be rather complete. In checking the thoroughness of the bibliography and list of hybrids, I used material that I had prepared

some time ago when dealing with an unidentified duck hybrid. I found only one obscure reference missing from the list given in the book.

This is a valuable compilation and long overdue publication on hybrid ducks. It will be useful to all of those interested in waterfowl hybridisation and to others searching for information on hybrid birds. I recommend it to anyone interested in the subject because of the exactness of the descriptions and the quality of the compilation. Its high price, which can be explained apparently by the inclusion of 16 pages of colour photographs, should not be a deterrent to its acquisition.

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The Summer Atlas of North American Birds

By Jeff Price, Sam Droege, and Amy Price. 1995. Academic Press, San Diego. 364 pp., illus.

This is a good and useful book. It is a well-organised series of maps based on the North American Breeding Bird Survey. However it is also a book with which I have some significant problems, because of the nature of the data on which it is based.

The authors have used the results of the North American Breeding Bird Survey (BBS). BBS is a wonderful collaborative program of volunteer data collection on the location and abundance of birds in midsummer. It is a credit to its originator and champion Chandler Robbins. The problems really lie with the limitations of the BBS methodology, and they readily show up in some maps. While I can point out some of these flaws, I am uncomfortable in criticizing the BBS. Such a critique would only be justified if I could define a better alternative. This I cannot do.

A comparison of two sparrow species is indicative of the type of problems I experienced. The Clay-colored Sparrow is a noisy bird with a distinctive song, that carries well in the morning air. Baird's Sparrow's song is much weaker and far more easily missed. The distribution maps imply that the Clay-colored is much more widespread and abundant than the Baird's. Recent work by Davis et al. (*Blue Jay* 54 (4): 185–191) found that in native prairie the Frequency of Occurrence of these birds was 40% and 34% respectively. This is not such an amazing difference. In this study, the researchers were concentrating on finding Baird's Sparrow, a bird they were very familiar with, while also recording all other species found. The different interpretation of abundance levels relates more closely with the survey methodology than with the number of birds in a unit area. The Clay-colored will be more easily observed by the road-oriented BBS, because of its

habit of using bushes beside the roadside. This may enhance its own apparent numbers over that of its field-loving cousin, the Baird's Sparrow.

The authors set themselves a formidable task, when they decided to use these data to prepare distribution maps. Their approach is logical and scientifically defensible. The maps they produced are easy to understand and use. I can, for example, readily get a sense of the distribution (and perhaps abundance) for the common hawks.

The data for Woodcock were considered too sparse to develop a map. This bird is actually very common, but secretive. It is most easily found in early spring when it performs its courtship ritual. This is long before the BBS season begins. Another shorebird, the rare Mountain Plover, however, is mapped. It is an open plains, more visible species. From BBS data, it appears to be virtually confined to Texas, New Mexico, Colorado, and Wyoming. Maps based on anecdotal evidence of this species, however, usually show a larger area that includes Montana and Nebraska.

Sora, another secretive species, which is under-represented by a mostly-daylight BBS census makes it to only the lowest density rating in southwestern Saskatchewan. In this general area we found that Soras were the most frequent prey remains in Great Horned Owl nests, suggesting a substantial population. This typifies another BBS failing.

So, how can you use an atlas based on a biased data set? First we must remember that, despite the weaknesses, these data were collected under a defined protocol. This makes the data more useful as a reference; from year to year, species to species and in plotting trends. As near as I can tell, the maps do show the heartland of a species' range. The reader must interpret the extent of the bird's peripheral area using other information. I found it most interesting

and informative to compare ranges on birds such as the flickers. I will use these maps as a ready reference when moving from province to province and state to state. It will not be a primary tool, but will supplement other information.

The authors have used their mapping technique to develop some species-richness derivative maps. This served to remind me that the most summer bird rich area in North America runs from New Brunswick through northern Ontario to northern Saskatchewan. However, Canadians should note that only southern Canada is covered. I am sure there is inadequate data from the northern half of our country.

So, buy the book, use it when and how you can and think about becoming a BBS volunteer. The authors have shown us, the birders of North America, the limitations of the BBS data. It is up to us to fill the blanks when someone repeats this exercise in 10 to 20 years. As a bonus, the book is illustrated by a sprinkling of top quality line drawings by David Beadle.

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Handbook of the Birds of the World: Volume 4. Sandgrouse to Cuckoos

Edited by Josep del Hoyo, Andrew Elliot, and Jordi Sargatal. 1996. Lynx Edicions, Barcelona. 821 pp., illus.

The previous volumes of *Handbook of Birds of the World* have already set a standard of excellence. It will be no surprise then, that this volume maintains this standard. It also covers some of the most brilliantly-coloured birds on earth, making it a particularly spectacular book. It starts with the subtly-coloured sandgrouse in various combinations of orange, chestnut and grey. Next come the pigeons and doves; birds which in America and Europe are dominantly plain greys and brown. We tend to forget that many tropical species are not only coloured with chestnut, yellow, emerald and blue but some have amazing head ornaments. Almost 40% of the book is devoted to the parrots, a group where feather colour goes through the roof. The cockatoos come in two basic versions; large black and impressive and smaller white ones that are equally impressive. Then there are the parrots proper, most of whom must have showered under a rainbow. Parrot colours are so bright and complex as to be wildly dazzling. Finally the book covers the cuckoos, a less flamboyant group but one not to be sold short. Besides the quaint roadrunners, the cuckoos also contain the turacos. These cute, teddy bear-faced birds are truly magnificent. Even the true cuckoos have members that are violet or emerald.

The well-written text extends our understanding by giving an extensive summary of the breeding biology of all the species covered. There is an introductory section that follows the standard pattern set by the previous volumes; Systematics, Morphology, Habitat, Habits, Voice, Food, Movements, Relationship with Man, Status, and Conservation. The section on pigeons is a fine example of the support given to the species accounts by the introductory account. Pigeons are not held in high esteem by many enthusiastic birders. If you read this section I assure you, you will have a different view and a greater respect for even the humble

Rock Dove. Pigeons in general, and the Rock Dove in particular, have many remarkable attributes.

Each species has a coloured plate, with the dominant illustration often being the male in breeding plumage. The text gives a detailed account of the bird's biology and status. A range map completes the species account. The authors use red upper case print to highlight the status of species at risk. Red highlights are very noticeable in the parrot section. For example, 17 of the macaw species, almost 50%, are highlighted. Overall about 37% are in serious trouble. This proportion is unmatched in any other group of birds. It appears that our desire to own a captive specimen of these dazzling birds, added to habitat destruction, has pushed so many species to the brink of disaster. In addition many species are range restricted, another stress on their survival. This list includes only those birds that are currently in trouble, not those that are already extinct.

I was drawn to the section on the Australian genus *Psephotus* as it contains some of the most brilliantly coloured of the world's parrots. One *Psephotus* member, the Night Parrot, was once considered extinct, but recent sightings have raised hopes that it may still live on. Sadly the reverse is true for its kin, the Paradise Parrot; hope has faded and the species is now considered extinct.

There is some variation in the quality of the plates, but the variation is from very good to superb. L. Sanz's illustration of the macaws is breath taking. I have opened to it several times and caught my breath on every occasion. To prove the validity of the artist's plates the book is also illustrated with some wonderful photos. Not only are these photos of excellent technical quality but the compositions are truly magnificent. The photo of a pair of Hyacinth Macaws is one fine example. So also is the charming photo of an Orange-bellied Parrot; the first ever taken of a bird at the nest. As well this is not simply a "mug-shot" collection; the selection of different poses helps underscore the biology given in the text.

I am confused by one photo, however. The White-crowned Turaco shown has a caramel coloured breast; my understanding is that all individuals of this species have green breasts. This is not a mix up in names for the White-crowned Turaco is the only turaco with a white crown.

In such a monumental work there are bound to be some minor errors. When I looked up Mourning Dove, the index led me to the African Mourning Dove. I needed to search for "American" Mourning Dove to find the text on this familiar species. I also found a missing reference in the index.

While this is a wonderful new book in world ornithological literature, it carries an underlying sad

message. Some birds, and parrots in particular, are in serious trouble. Perhaps publishing this volume, coupled with the prestige being built by the *Handbook* series will alert the world to our impending loss. The information this book contains is a great foundation for logical decision making. If not, then the time will come when all we will have to remind us of these dazzling birds are the delightful plates and charming photos in books like this one.

ROY JOHN

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Red-winged Blackbirds: Decision-making and Reproductive Success

By Les D. Beletsky and Gordon H. Orians. 1996. University of Chicago Press, Chicago. 294 pp.

Many of us, who work in the environmental field, have felt the frustration of ignorance. Frequently we do not have those vital pieces of information that would bring a more successful conclusion to our endeavours. The main reason for our lack of understanding is that the knowledge is difficult and time consuming to obtain. Beletsky, a research scientist and Orians, a professor emeritus, have spent sixteen painstaking years to bring us a better understanding of the Red-winged Blackbird's strategies for reproductive success. The book is organised into four sections. The first is an introduction to the author's project and study area. The second and third cover the influence of decisions made by females and males on the reproductive success. The final section brings the work together in a coherent conclusion, contrasting male and female decisions brought on by the environmental pressures.

The authors have used the data they have collected to assess the impact of habitat availability and selection, the choices made by females on where, when, and how much effort to put into nesting. Males must establish a territory and exert dominance to maintain control against other males. Beletsky and Orians examine each factor, like food supply or nesting dates to look for relationships to the species survival. Concepts that are not substantiated by the data collected to date are set aside and alternative explanations are sought. This thorough, unbiased scientific approach results in a much better understanding of this bird's behavioural ecology; better than we have for most (if only we knew as much about Burrowing

Owls). The results are impressive. I expected to see details such as the territory size (typically about 150m²) or harem size (about four females/male). I was surprised to learn that only a small percentage of adult Redwings are responsible for the maintenance of the population. Indeed, some 30% of females never succeed in producing a living offspring. This gives the population a greater vulnerability than at first appears - remember population decline of Starlings has led the British to add it to their species-at-risk list. The average breeding years for a female are 2.4 but the authors have records for individuals reaching 11 years. Generally a longer breeding record is a better breeding record.

The authors examine the current models used to explain avian contest behaviour as they apply to the territoriality of Redwings. Using these models they predict behaviour and then compare the output to their documented observations. Each model has obvious deficiencies, which are explored carefully.

This book details a careful scientific study and will be valuable to more than those interested in Red-winged Blackbirds. It contains many ideas on the protocols for data collection and interpretation. The authors provide new insights from using field data, experiments and game-theoretical models. It will be useful to behavioural scientists and biologists in all sectors of biology and will prove an excellent text for those studying reproductive behaviour.

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The Butterflies of Canada

By R. A. Layberry, P. W. Hall, and J. D. Lafontaine.
University of Toronto Press, Toronto, Ontario, Canada.
280 pp., illus. Cloth \$100; paper \$29.95.

Somehow I received an invitation to participate in the unveiling of a new Canadian scientific publication, *The Butterflies of Canada*. I love natural history but do not belong to any nature clubs or organizations, and had never met anyone who studies these insects. However, I have been a "closet lepidopterist" since I was five years old. Most people bring home trinkets from faraway places, I bring home colourful butterflies.

I had a chance to test this book on a Victoria Day weekend visit to the Mer Bleue peat bog on the east side of Ottawa. A brown medium-sized "flutterby", as my zoology professor always referred to them, landed on a tree in a wooded bog transition zone. I took a long hard look at this insect as it was certainly not one I had ever seen before.

Back home I got out the book and rifled through the colour plates and found my "friend" in seconds. Jutta Arctic was its name and it was distinguishable as a male. The distribution map showed most of Canada as its home and there was a reassuring dot on the map for its presence in Ottawa.

Its favoured habitat was described as "spruce and

tamarack bogs" and more specifically that it prefers the edges of treed areas to more open spaces. Bingo! Furthermore, it was noted that these elusive creatures fly in late May/ early June every year in the Mer Bleue! Their cycle differs elsewhere. As I read, it felt as if the authors were looking over my shoulder. What a warm feeling!

It is often relatively easy to find fault (either small details or broader aspects as layout and so on) with combination scientific/popular textbooks and I have always measured new books against *Freshwater Fishes of Canada* (1973). This one surpasses it. My only suggestion regards the size of the book. Could a "pocket version" containing only the plates, identification and range maps be produced to carry conveniently into the field? This would complement the present book with its full text which then could be kept home for end-of-the-day reference.

The Butterflies of Canada is a first class publication that can be used by people of any age or education. Well done, gentlemen.

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Discovering Dinosaurs in the Old West

Edited by M. F. Kohl and J. S. McIntosh. 1997.
Smithsonian Institution Press, Washington, D.C. xvii +
198 pp., illus.

Nineteenth century North American paleontology is arguably dominated by two names: Edward Drinker Cope and Othneil C. Marsh. Both Cope and Marsh worked for separate American institutions and in later years were often caught stepping on each others' toes as they described literally hundreds of new species of fossils mostly found in the American west. Yet both did relatively little field work, and instead hired crews to work for them (and at times members of these parties also felt a little crowded with the rival crew only a few miles away). Though much has been written about these paleontological kingpins and their rather public rows, little has been documented about the men in the trenches; the less scientifically bent, but more exploratory nature of the collector. The recent remedy is the published journals of one of Marsh's field leaders Arthur Lakes (1844–1917).

The editors of two of Lake's journals, Kohl and McIntosh, have produced *Discovering Dinosaurs in the Old West* based on the collecting years of 1878 and 1879. Noted for his paintings of field work (some of these are scattered throughout the text) as

well as his collecting efforts done mostly for Marsh, Lakes explores the world of sauropod dinosaurs, camp invasions by salamanders, and snowstorms experienced while collecting. Lakes, primarily self taught in the arena of paleontology, illustrates in his own hand the separation between scientists and collectors. Whereas Charles Darwin, while traveling aboard the Beagle, was notably affected by the ideas presented in the few books he brought along (including Charles Lyell's *Principles of Geology*), Lakes mentions in unusual brevity the reading of Robert Chambers' scientifically disruptive piece *Vestiges of Creation* as well as some of Darwin's work. Great descriptive lengths are given of the fauna and flora of Wyoming and Colorado, people, places, and events, but little in terms of why he is collecting ("July 27 [1879] Read Darwin, wrote letters, men cut hair..." (page 129)). This is most assuredly an unfair comparison, but it illustrates that Lakes, and many of his fellow workers, worried more about enjoying and experiencing life at the moment, than whether a new fossil discovery contributed or deterred from the paleontological topics of the day.

The text is full of tales of sauropod discoveries and other Jurassic and Cretaceous creatures; many of them would fuel the row between Cope and Marsh.

Of these, the editors supply numerous explanatory notes as to their eventual repository in the annals of paleontology while expanding the personal descriptions of other historical figures mentioned by Lakes. The surrounding events of discovery and excavation are also numerous and entertaining. Flooding of camps, downpours, caving in quarries, extricating fossils in the January snow, and nervous twitches about "desperado's" and Indians fill this little volume. It is in these tales that the fluidity of the text excels. Periodically, Lakes muses, if somewhat contortedly, over things more ethereal. While on route in the mountains he notes that "[t]his gradual transition of [one biogeographic] zone into [another] zone reminds one of the gradual passage of geological periods into another" (page 38). These ponderings are in stark contrast to another fact of early exploratory work. Generally the philosophy was, if it moves, stone it or shoot it. Seemingly, every day some poor thing was killed in the name of food, sci-

ence, irritation, or enjoyment [how easy it is to put our own conservational standards upon any character of the past]. Though Lakes contributed to these endeavors, much of this activity was done by his fellow collector William Reed (1848–1915).

All these collectors were in search of something, whether it was directly related to paleontology, or something more personal. For Lakes, between 1878 and 1879 it was bones larger than "Hercules war club" (page 14). *Discovering Dinosaurs in the Old West* is a beautiful, though at times repetitive, example of first hand experience in the trenches of paleontology in 19th century America. What is discouraging is that it is too short. These journals would have even been more valuable and entertaining if Lakes himself would have composed a more expansive tale of his life in the field.

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A Travel & Site Guide to the Birds of Costa Rica with Side Trips to Panama and Nicaragua

By Aaron D. Sekerak, illustrated by Elissa Conger. 1996. Lone Pine Publishing, Edmonton, Alberta. 256 pp., illus. paper \$22.95, U.S. \$16.95.

Costa Rica, with over 850 bird species tucked into a country smaller than Nova Scotia, has become one of the most popular birding destinations in the world. It is served by two outstanding accounts of its birdlife, but information on where to go and how to get there has been limited to Keith Taylor's self-published *A Birders Guide to Costa Rica*. This new book would seem to either duplicate (or compete with) Taylor, but its approach is very different.

In fact, this is an unusual finding guide. In the finding section for each site the author quotes extensively from his own experiences there: for example, a short passage from the description on Golfito reads: "wading in the Heliconia-lined stream was productive for viewing hummingbirds. I spotted a nest on the underside of a Heliconia leaf and shortly thereafter a Bronzy Hermit settled down to incubate the eggs inside... I'll never forget a stunning White-necked Jacobin that hovered 2 meters (6 feet) away at eye-level for 10–15 seconds." This discursive approach gives the book an immediacy that more prosaic finding guides lack - it's fun to read. The down-side is that it is very space-consuming, and there are only 48 sites in total described for Costa Rica, plus a couple each for Panama and Nicaragua.

The introduction first discusses the distribution of Costa Rican birds, dividing the country into seven zones, each with a different grouping of species. These species are then listed in full in an appendix at

the end of the book. There follows a section on birding in Costa Rica, with assorted details the traveller might find useful. The choice of these is puzzling: much basic information is not covered (you are told to use a general guide book) but on the other hand there is a section on binoculars and 'scopes which offers little that is new, and another on litter!

The next seven chapters correspond to the seven zones identified in the introduction. Each opens with a short general section describing the zone as a whole, with a map showing the location of the sites being covered, information on travel to the zone, and a listing of the birds special to it. Sites are then covered in succession in the manner described above, usually with a good detailed map of each area, and a listing by season of the species encountered there by the author or by other observers he knows. The immediacy of the text is enhanced by delightful line sketches and by a brief vignette for each zone, recounting some especially memorable experience there.

The book concludes with a page on Cocos Island, a table listing 77 specialty species with a brief note on distribution and where to find each, the Panama and Nicaraguan sites as "side trips", and a checklist of Costa Rican birds. There are five blank sides for notes, but no index!

I'm very ambivalent about this book. Some well-known sites are absent, and the information provided is very uneven. For example, many of the sections on travel to zones are so brief as to be of little practical value. The zones themselves are logical divisions for bird distribution, but not always for travel, so the route to Monteverde passes fairly closely to Puntarenas, but they appear in different chapters. I'm

also not sure of the utility of the site lists: the author feels these will indicate the most likely birds to be seen because they were the birds he saw, but in the tropics the sheer variety of species makes this rather questionable. I once spent three days largely confined to the balcony at Rancho Naturalista, and saw a different crop of birds each day!

The two most pronounced weaknesses are easy to fix in a new edition. The book desperately needs an index, and there is much repetition. For example, the table on page 10 reappears on page 215; many birds seen by the author are noted in boldface in the text and again in the site lists; and specialty birds are listed under the zone, again in the appendix, and again in the list of bird specialties. Some repetition is reasonable, but this calls for some tight editing.

Life of the Flycatcher

By Alexander F. Skutch, illustrated by Dana Gardner. 1997. The University of Oklahoma Press, Norman, xiii + 162 pp., illus. U.S. \$40.

To the North American the Tyrant Flycatchers may lack appeal - they often seem rather dingy birds that are hard to identify, have monotonous little songs, and that sit around doing nothing. A visit to the tropics reveals a thoroughly confusing array of many more of these creatures, at first glance one of the less-welcome challenges facing the birder on a trip to Central or South America.

This book shows how inaccurate these impressions really are. In it, Alexander Skutch celebrates the rich diversity of this huge (over 380 species) family, and draws on his own amazing wealth of first-hand experiences and observations to recount the wide variety of behaviours and life styles that can be found, particularly among its tropical members.

This is the latest in a rather informal series of *Life of...* books that Skutch has written over some 20 years, each covering the life histories of a particular family of birds. Here the author confines himself to the flycatchers proper, excluding contingas, becards, and manakins. There are eleven chapters covering such topics as Food and Foraging, Courtship, Nests, and Young and Their Care, together giving a comprehensive view of the Tyrannids. As in the earlier volumes, the bibliography appears at the end, but separated into the various chapters.

So the book has its faults, but it is still a useful contribution. It must be assessed in the context of what else is available. This means Taylor's book, which has quite different problems of its own, and which (at least in my edition) covers even fewer locations. In many ways the two books are complementary, as Taylor has comprehensive site lists and attempts more route directions. The current volume is full of useful snippets of information, has better site maps and format, and lists some new sites. I thoroughly enjoyed it and it made me want to visit Costa Rica again, and I'll certainly take it with me when I go.

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The style will be familiar to anyone who has read any of the author's other books - highly readable and full of insightful anecdotes, while viewing his subjects in very human terms. In fact, he takes strong exception to the term "tyrant", as he feels this conveys an inappropriate picture of a family that is in general "mild and inoffensive", although given that some of its larger members are "valiant". He even goes so far as to expurgate the name tyrant or tyrannulet from the specific names in the text, substituting flycatcher, and creating confusion for the hapless reader in the process!

But one must take Skutch on his own terms, and this book provides a fascinating overview of the New World flycatchers. Once again one is amazed at the sheer breadth of the author's observations, with detailed nesting observations on over 40 species of this family alone. Admittedly this has meant that he has not been able to undertake the more intensive studies that have been done on some North American species, but given that the only information available on many tropical species in a range of families is his own it is difficult to fault his approach.

Life of the Flycatcher is an interesting, thoughtful, and very readable overview of the lives of a fascinating group of birds.

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BOTANY

Illustrated Companion to Gleason and Cronquist's Manual: Illustrations of the Vascular Plants of Northeastern United States and Adjacent Canada

Edited by Noel H. Holmgren with artistic and editorial assistance of: Patricia K. Holmgren, Robin A. Jess, Kathleen M. McCauley and Laura Vogel. New York Botanical Garden, Bronx, NY 10458-5126. XVI + 937 pp., illus. U.S. \$125.00.

In *The Canadian Field-Naturalist* 106(3), 1992, I published a short review of Gleason and Cronquist's manual in which I congratulated Dr. Cronquist for having brought this most useful second edition to completion. Now there is an absolutely wonderful volume to accompany it which will be invaluable to anyone using the manual. There is a short introduction on the history of floras of the region which have been produced by the New York Botanical Garden, the illustrators, and an explanation of the plates, and literature cited.

The manual follows the family sequence that Cronquist proposed in his *Integrated system of classification of flowering plants* which was published in 1981 rather than the Englerian system of earlier publications. This posed a problem to consult illustrations in Gleason's three volume *New Britton and Brown Illustrated Flora of the Northeastern United States and Adjacent Canada*. Now in the *Illustrated Companion* the illustrations are in the same order as the manual with manual page numbers to be found at the top of each page under the generic names. In addition to the drawings used in previous volumes some new or replacement illustrations have been

added together with a great many additional drawings of flowers, fruits, seeds and other small parts to assist in the recognition of individual species. This has been a tremendous effort on the part of all of the individuals concerned in the organization and production of the work.

In addition to the drawings there is a useful appendix which provides a comparison of names used in Gleason and Cronquist's *Manual of Vascular Plants of Northeastern United States and Adjacent Canada, second edition* (1991) with those used in *Flora North America* (volume 2, Pteridophytes and Gymnosperms, 1993; volume 3, Magnoliophyta: Magnoliidae and Hamamelidae, 1997), an index to common names which are followed by scientific names in brackets and page numbers and an index to scientific names with page numbers. A map depicting the area covered by the volume can be found on the front inside cover and adjacent page and back inside cover and adjacent page.

Again, all those involved in the production of this excellent work are to be congratulated.

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Wetland Plants of Ontario

By Steven G. Newmaster, Allan G. Harris, and Linda J. Kershaw. 1997. Lone Pine Publishing, Edmonton. 240 pp., illus. \$24.95.

It is remarkable, really, that a field guide to wetland plants in Ontario has not been previously published, given the high profile these habitats have received in the province and indeed throughout southern Canada in recent decades. The wait for such a guide appears to be over.

Wetland Plants of Ontario is a physically small, well-constructed book which won't quite fit in your jeans back pocket (at least, not in mine) but will slip into a side jacket pocket or pack-sack easily enough. It is light-weight but protected by a durable, plasticized, flexible cover that seems particularly well suited to the perils of field use, especially in wetlands. While probably technically not water proof, the section I intentionally soaked dried completely in a few minutes without any smearing

of type or fusing of pages — and virtually wrinkle free too.

The guide is stuffed-to-bursting with information, treating over 450 species of vascular and (here's a nice touch) bryophyte species. Species are arranged within large, practically selected groupings such as sedges, shrubs, aquatics, ferns, etc. These mostly work well, though some questionable associations result (e.g. quillworts (*Isoetes*) are placed in "Aquatics" (page 157) not with "Ferns and fern allies" where other aquatic and semi-aquatic pteridophytes are logically grouped). Most species are illustrated with small (typically 4 to 5 cm tall) colour photographs of the plant *in situ*. These effectively demonstrate salient identification features in the vast majority of cases. Despite their small size the photographs are mostly sharply focused and attractively arranged. Some of the photographs in my copy were a bit muddy in appearance and others — particularly

graminoids — did not show great detail, but a measure of that is to be expected. Numerous excellent pen and ink sketches have been added to express features that were difficult to represent by photography.

In a welcomed expression of priorities, very little space is given to introductory material and lengthy explanations of methodologies, objectives, and so on. In a further example of this economy, the authors provide illustrated keys which take the user to an end point which often identifies a group of taxa to be considered. An interesting and practical approach.

Wetland Plants of Ontario rarely expends more than half a page to provide a concise yet technically reliable description for a given species. The type is a bit small for my middle-aged eyes but it is an acceptable compromise that permits more text to be provided. An extensive "Notes" section which can take up much of the remaining page usually treats several similar species. Ecological information, safety considerations (e.g., poisonous taxa), anecdotal and nomenclatural information, rare status, and distributional descriptions are also included here. Unfortunately, so too are frequent repetitions of the "aboriginal use" anecdotes that litter the pages of many other popular botanical guides as well. I wish that the authors had spared us these largely unverifiable and questionable reports and had instead given us more of their usually authoritative and applicable information.

The overly general descriptions of distribution, including sketchy provincial status designations, constitute the only consistently poor feature of *Wetland Plants of Ontario*. The reader has a right to expect that range statements reflect the focus of the guide in which they appear. That focus of this guide is described as being "on common and indicator wetland plants of central and northern Ontario" (page 7). Stating that Green Alder extends "from Newfoundland to Alaska, south to California and South Carolina" (page 25), however, is a misleading and unhelpful description of the range of this Boreal/sub-alpine shrub for users in Ontario. Many comparable examples were noted throughout the book. That unfortunate deficiency is not critical, however, since the nomenclature and taxonomy are up to date, thus this information can be looked up elsewhere.

All in all, *Wetland Plants of Ontario* is top-notch. It deserves a place in the pack-sack of anyone exploring the remarkable diversity of eastern Canadian wetlands, especially those slogging through the bogs, swamps, and fens of the Canadian Shield of Ontario.

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ENVIRONMENT

People and the Land through Time: Linking Ecology and History

By Emily W. B. Russell. 1997. Yale University Press, New Haven and London, 306 pp., illus. U.S. \$35.

Naturalists and ecologists in recent times have emphasized the holistic nature of the biosphere and its ecosystems. That humans and other species live in a complex web of relationships, in which what happens to one species and its habitat has far reaching affects on other species and habitats, is an understanding that is commonly held by those who study and enjoy the natural world. What is not so commonly understood is that these biological interconnections have chronological as well as spatial dimensions. Disturbances in ecosystems, particularly those induced by human intervention, can have impacts that extend over many centuries. It is the contention of Emily Russell, in *People and the Land through Time*, that unless we understand the influence of past disturbances on ecosystems we cannot fully understand them, or make wise decisions concerning them. "I have written this book", she states, "to help point to different aspects of current environments that bear the imprint of various past human activities, which must be considered in order to understand the current processes." This is

done with compelling clarity. Russell also hopes "that readers will carry away an excitement for including human history in ecological studies and ecology in historical studies." My own reaction to the book is that this too has been achieved.

The book has three parts. In the first part the author describes the various techniques — the detective work — of reconstructing the story of ecological disturbances, and of the subsequent changes to ecosystems, which have occurred in past times. Information from written documents, like Great Britain's Domesday Book of A.D. 1086, is compared with that gleaned from the examination of current physical features by such means as aerial photography, and from the study of growth rings in trees and pollen grains and plankton in sediments. The second part of the book, with numerous examples from countries around the world, explores how humans have altered natural ecosystems by activities like setting fires, introducing species to new regions, cutting forests and tilling land. To clinch her argument that Historical Ecology contributes to the understanding of ecological issues, Russell devotes the third section of her book to a series of illustrative case studies.

Although intended as a reference for professionals, and as a textbook for students, a much wider public will find the book both interesting and enlightening. The text is readable. There are many black-and-white pictures of fine quality, which helpfully illustrate points made in the text. These are supplemented with a variety of maps, tables, and graphs. Scientific names for species are frequently used in the graphs and tables, which is important for accuracy. The addition of common names, however, would have made these more useful to a greater number of people. The footnotes are contained in a 45-page section at the end of the book. They provide a wealth

of resource material, although footnotes at the back of a book are more cumbersome to check than those at the bottom of a page.

People and the Land through Time is an important addition to ecological literature; a volume that everyone promoting a holistic understanding of the natural world, and seeking to preserve its integrity, would be well advised to read.

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Nature's Services: Societal Dependence on Natural Ecosystems

Edited by Gretchen C. Daily. 1997. Island Press, Washington, D.C. 392 pp.

In this day and age with news focusing on economic ramifications of human activity, people with an interest in a healthy biosphere find themselves asking or being asked what value does a natural system provide society? One can argue this is a very human interest only view, but it is a view used more and more to provide reasons for some level of protection. The general argument being: the more value to society the greater the need to preserve or conserve. This implies a means to prioritize. The priorities are set often using the perceived benefit as justification. How are these benefits or values arrived at?

G. C. Daily has assembled twenty chapters or papers from thirty-two world renowned experts which address some of the issues involved in determining benefits or value provided by ecosystems or components. The chapters have been organized to provide, first, a general overview then progress finally to more specific case studies. The chapters found at the intermediate point of this gradient deal with components and major biomes. The reader is provided with references for each chapter as well as an index to utilize for further research. All papers are highly read-

able and should be understood by readers with minimal technical training. Only a few typos were noted in the text.

As one reads through the book they become aware of the wealth of information which is available. They also are confronted by the enormous gaps which exist in mankind's understanding of the world in which he/she lives. The lack of scientifically based information on which some of these decisions have been made, I'm sure, would trouble most. This book provides an insight for those involved in the research field, policy setting or the general consumer.

Dr. Daily has edited a book which (1) provides a history of ecosystem valuation, (2) describes present state of scientifically based information available for major biomes, (3) provides description of some key components and their valuation, and (4) specific case studies of the valuation process. This information is presented in a highly readable fashion. This is a book I would not hesitate to recommend to those involved in the valuation of the world's ecosystem services.

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Prairie Conservation: Preserving North America's Most Endangered Ecosystem

Edited by Fred B. Samson and Fritz L. Knopf. 1996. Island Press, Washington, D.C. and Covelo, California. xii + 339 pp., illus. Cloth U.S. \$50; paper U.S. \$28.

Grasslands are the most imperiled major ecosystem on a worldwide basis. This book covers the grasslands of the North American Prairie in four parts. Part 1: Value in Prairie describes the stunning wholesale alteration of the prairie as it has been debuffaloed, dewolfed, and degraded. It also emphasizes the economic value of the prairie, as

quantified by the market place and noneconomic values as well. Part 2: Prairie Ecology includes four chapters on the ecology, with management recommendations, for tallgrass prairie, mixed prairie, shortgrass prairie, and wetlands. Part 3: Prairie Legacies has a chapter each on invertebrates, fish and aquatic resources, amphibians and reptiles, birds, and mammals. Part 4: Prairie Conservation describes eight different conservation programs, each a chapter in length, in the prairie, with the final

chapter dealing with the management challenges in the twenty-first century. The book concludes with a 10-page species list of common names used in the text, an extensive literature cited section, a list of contributors, and an index.

The goal of this book is to "... increase awareness, information, and understanding ..." of the prairie. In general, it has done an excellent job of meeting that goal. The book, however, is not without error or shortcomings. For example, Figure 3.1 showing the prairie distribution at the time of European settlement is much too restrictive. The limits of shortgrass prairie were farther west than indicated. There is no indication on that map or in the text that the tallgrass prairie extends into western Ontario. The shortgrass prairie is replaced by fescue grasslands to the west, not just to the north as the text indicates on page 67. Nor is any mention made of the fescue grasslands in the Cypress Hills of Alberta and Saskatchewan.

My major criticism, however, is that some chapters, such as fish and aquatic resources and amphibians and reptiles, contain little or no information on the Canadian prairie. These authors seem to assume the prairie ends at the 49th latitude. Both chapters could have been greatly strengthened by some

Canadian content. The chapters on invertebrates, birds, and mammals offer much better coverage.

I am surprised that the Long-tailed Weasel was omitted from Table 11.2 listing Great Plains mammals that are extirpated, declining, or extinct.

Part of this book were previously published in the 1995 Transactions of the North American Wildlife and Natural Resources Conference.

The need to preserve the prairie and conserve biological diversity has been recognized by several federal, provincial, and state agencies, nongovernmental organizations, and landowners. The various conservation action plans, joint ventures, and partnership initiatives documented in this book gives the reader hope that the biological uniqueness of the prairie will have a sustainable future.

The strength of this book lies in its clarion call for continued action to stem the loss of diversity and richness in the prairie ecosystem. *Prairie Conservation* is a valuable resource for a wide range of disciplines interested in conservation, sustainable agriculture, and other resource management fields.

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Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources

Edited by M. S. Boyce, and A. Haney. 1997. Yale University Press, New Haven and London. xiv + 361 pp., illus. U.S. \$40.

Ecosystem Management: Applications for Sustainable Forest and Wildlife Resources, a collection of 16 papers, is based on the results of a symposium on ecosystem management held at the University of Wisconsin-Stevens Point between 3–5 March 1994. However, the papers in the book have been updated to account for recent research and insight. The book is organized into five principle sections, including: Ecological Framework; Disturbance: Techniques and Classification; Making It Happen; and Future Directions.

Ecosystem management is not a new concept [see a recent volume of *Landscape and Urban Planning* 40(1–3) focusing on ecosystem management] although its implementation continues to prove a challenge for scientists, land managers and policy makers alike. The introductory papers capture, in a relatively succinct manner, the range of complexities and nuances characterizing ecosystem management. In particular, they highlight the dilemma caused by the lack of certainty in our understanding of ecosystem management with the need to make decisions and policy based on often incomplete information. Ecosystem management is,

indeed, a working hypothesis. As well, several papers seek to enhance our understanding of ecosystem management by illustrating its differences and similarities with such disciplines as ecological science, landscape and/or the "greater" ecosystem approaches.

In general, the section Ecological Framework outlines the core aspects and concepts behind ecosystem management, including the need for integrated planning, adaptive management, the critical role of well-developed monitoring systems and the establishment of feedback mechanisms between science and management. Of note, it also highlights the role of different scales in ecosystem management. This is achieved by providing papers covering landscape ecology, the preservation of rare species, and the role of macronutrient cycling.

Within the other major sections of the book (e.g., Techniques and Classification and Making It Happen), the challenges of application and implementation are addressed. For example, a paper on the role of geographic information systems (GIS) and remote sensing provides a useful case study from Wisconsin, as do papers on the use and value of hierarchical classifications systems, population viability analysis (PVA), ecological restoration, and ecosystem protection.

Illuminating, however, is the content that is absent from this volume. While providing a strong argument for an integrated and comprehensive framework to guide ecosystem management, papers tend to be niche-oriented and sectoral in focus. In large part, this may be a product of necessity. However, it does not account for a lack of analysis and discussion on the socio-economic, institutional, and policy issues identified in introductory papers as a fundamental aspect of ecosystem management. While good science is fundamental to ecosystem management, greater emphasis on its role as a framework for planning and decision-making is required.

Despite this omission, *Ecosystem Management* provides an insightful, if not comprehensive, assessment of the current status and understanding of the concept and its application in complex contexts. While the focus and examples are strictly oriented to the United States, many of the articles will inform the Canadian scientist and manager interested in the topic; especially those involved in the management of our forests and their wildlife resources.

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Null Models in Ecology

By N. J. Gotelli and G. R. Graves. 1996. Smithsonian Institution Press, Washington. 368 pp., illus. U.S.\$30.

Field naturalists are a pragmatic bunch of people. We learn our natural history one step at a time as we familiarise ourselves with nature's rules. Bogs are where we find Pitcher Plants. Lakes have White Water Lilies. Deciduous forests have Black-throated Blue Warblers. Ephemeral ponds in deciduous forests have Blue-spotted Salamanders. Often we acquire this knowledge from an older more adept field naturalist who shares with us the rules acquired over many years of practical experience in the field.

Good naturalists may know where to find things; professional ecologists, in contrast, are sceptics. They will observe that not all bogs have pitcher plants, not all lakes have White Water Lilies, and not all forests have Black-throated Blue Warblers. Are naturalists therefore discovering rules of nature, or simply inventing convenient stories to enrich their lives? A good naturalist may be equally sceptical of this scepticism: perhaps the inability of professional ecologists to find patterns arises out of their ignorance about nature. Too much time in the library and lecture theatre, and too much specialisation, means, perhaps, that the professional's scepticism is just a convenient way to avoid admitting ignorance.

Yet, the sceptic's view may have its merits: how many of us have gone to a habitat that "looks perfect" and yet failed to find the species that we sought? Our rule of pattern has been challenged. Do we then have to explain it away with an added fact? Past grazing? A fire? No dispersal? No pollinators? Over-collection? Acid rain? Climate change? Because it is so easy to always come up with an explanation for pattern, or the lack of it, professional ecologists have erected a rather intimidating series of rules for the evidence that must be provided to demonstrate that a pattern is real.

The general procedure is that one must first have a *null hypothesis*, that is, a description of how the

world would appear if a certain pattern did *not* occur. Then one collects real data from the field. Only if these real field data depart "enough" from the null model, do we accept the pattern exists. This of course, is just a rephrasing of the scientific method. It seems straight-forward. Yet, over the past decades, there has been a surprising amount of acrimonious and divisive debate about how one constructs null models.

Before we move on to the book in question, one more piece of background is necessary. The construction of null models is not as simple as we might first suppose. Consider the question: is there pattern in the ecosystems of Algonquin Park? Depending upon the null model, we might answer either yes or no. If the null model assumes that all species can occur anywhere, then almost certainly we will reject the null model, it being unlikely to find fish nesting in the trees or birds living in the bottom of lakes. But if the null model, instead, proposes that all lakes will have the same kinds of fish, or all stands of deciduous forest the same spectrum of birds, we may well find it much more difficult to reject the null model. Most lakes and deciduous forests in Algonquin Park, do, after all, have similar species. In this case, we have used our existing knowledge of nature to create a biologically real null model. But the more biological realism we put into the null model, the more likely that nature will fit it! Thus, professional ecologists have become stuck upon the issue of how much real biology ought to be put in a null model. If we construct a very realistic null model, should we be surprised when we find that nature conforms to it? And if nature does conform to a realistic null model, are we therefore justified in concluding that there are no patterns in nature?

Given this background, I was most interested to see how these topics might be covered in *Null Models in Ecology*. Gotelli and Graves take us through many of the main topic areas in which null

models have been discussed: species diversity, relative abundance, niche overlap, size ratios, co-occurrence, species-area relationships, biogeography, and food webs. In doing so, they cover familiar ground for many of us. Perhaps part of the reason for the familiarity can be found in the introduction: "... we contacted a number of colleagues and asked them to send us reprints and give us their perspectives on null models in ecology." Many of these are the same American zoologists who have dominated the literature on this topic for the past twenty years. The book does an admirable job in covering the perspectives of this group of scientists.

The task of an author, however, is not just to do the easy work and summarise the work of a few colleagues, but to provide a fuller perspective on the discipline, particularly drawing attention to broader issues of historical context, overlooked work, and de-emphasising familiar and perhaps over-worked examples. Here Gotelli and Graves have let us down.

Canadians will have a particular perspective on this failure. Although Gotelli and Graves say on page 1 that the term null models was coined by two Americans, Colwell and Winkler at a conference Florida in 1981, in fact the word goes back at least a decade earlier to the pioneering work of a Canadian ecologist, Chris Pielou. Pielou's work, summarised in two books in 1975 and 1977, is full of descriptions of "models" that provide "null hypotheses" for the structure of ecological communities. She follows in a long lineage of prominent ecologists who have studied plant communities along gradients (e.g., Tansley, Clements, Ellenberg, Gleason, Whitaker...) yet her work has been routinely and consistently overlooked by the American null models school, not even being cited in many recent so-called reviews (see Jackson 1981 for an independent critique). Gotelli and Graves at least cite some of Pielou's work in passing, and call her a pioneer, but after this bit of foreplay, we are left disappointed. Indeed, they do not even seem willing to take personal responsibility as authors for the obvious conclusion that her work has been overlooked; when this opinion is expressed, they invariably credit Simberloff and Connor for the insight. You will note that the list of topics in the preceding paragraph does not include gradient models of plant communities, yet this is the area in which an entire discipline of null models and tests has evolved, largely with work by Canadian scientists. Any responsible history would begin with a chapter on this topic. The first application of Pielou's null models was by Pielou and Routledge (1976), examining patterns in salt marshes from Nova Scotia to Manitoba. Gotelli and Graves briefly describe the work (on page 246) in the sort of detail you would copy from an abstract, but they fundamentally fail to explain, or perhaps even understand, the significance of this work in the

analysis of communities. Further, they irritated me personally by ignoring the only two other studies of vascular plants which have used Pielou's methods — my work on lake shores (Keddy 1983) and Shipley and Keddy's (1987) work in marshes. All three of these studies found important similarities in the way in which plant communities depart from null models, with significant implications for debates about community organisation. Further, Shipley and Keddy spent some time discussing the problem of erecting and testing null models in plant communities. None of this is discussed by Gotelli and Graves. Indeed, Pielou's entire body of work on gradients and null models is tucked away in the second last chapter on biogeography. One gains the strong impression that Gotelli and Graves already had written their book from their friends' reprints, and then discovered Pielou's work by secondary sources. Rather than expend the necessary effort to read her books and revise their manuscript, which would have meant re-writing at least the entire first chapter, they apparently decided to take the easy way out and stick with their biased history (null models as a magnificent discovery of American zoologists) with some short sections on Pielou as an afterthought. Readers deserve better.

In the final chapter of my book *Competition* (Keddy 1989), I discuss the degree to which a small group of ornithologists have hijacked the field of community ecology, in part by ignoring the developments in ecology that took place earlier in the century. (Needless to say, this book also is not cited by Gotelli and Graves, even though they talk a good deal about competition and pattern!) Their perspectives on null models adds to the accumulating evidence that the biggest trouble with community ecology since MacArthur has been ornithophilia: the inordinate emphasis upon a small colourful group of organisms that may be a fine hobby but are relatively insignificant when measured by criteria such as biomass or number of species (This is, after all, a planet of insects and plants). Perhaps it is instructive that Graves is a curator in the Division of Birds at the National Museum of Natural History, Smithsonian Institution.

In conclusion, naturalists will probably not care all that much about null models, although the book would provide a salutary reminder that not all patterns we claim to see may really exist. Practising ecologists may want to have copy upon their shelves because the book does illustrate the status quo in the discipline, blemishes and all, but I still would refer serious practitioners to Pielou 1975 and 1977. Authors of books are duty bound to cover their topic responsibly, and I felt both saddened and frustrated that Gotelli and Graves missed an important opportunity to unify ecology and set the historical record straight.

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MISCELLANEOUS

John Muir: Apostle of Nature

By Thurman Wilkins. 1995. Oklahoma University Press, Norman. xxvii + 302 pp., illus. U.S.\$24.95.

In this most recent volume of the series *Oklahoma Western Biographies*, Wilkins provides an excellent account of the life, work, and contributions of this towering conservationist. Muir was a complex and contradictory individual, with an early childhood in Scotland until his tyrannical father took the family to Wisconsin. Muir's early initiatives included a diversity of curious inventions, university studies in botany, and a deep attachment to the first of his several surrogate mothers. As a pacifist, he avoided the draft of the Civil War by botanizing in Ontario, followed by work in saw mills in Indiana. Muir's ever deepening interest in nature led to his thousand-mile walk from the Midwest to the Caribbean. During his famous first summer as a shepherd in the Sierra, Muir reacted to the scourge of the sheep as "hoofed locusts" but responded to the dramatic scenery with a pantheistic spiritualism. Millwrighting in Yosemite enabled study of the impact of glaciers (amid some dangerous mountaineering) and subsequent geological controversy. Muir's efforts brought contact with scientists, offers of jobs, and academic recognition. He expanded his travels in the West and North, and became more serious and successful about his writing and speaking. Muir's marriage, two daughters, and horticulture at the family ranch became large facets of his life. Beyond his conservative ethic, his lasting specific contributions involved Yosemite National Park, the National Forestry Commission, protection of the petrified forest, and the Sierra Club, of which he was long first president.

Accompanying Wilkins' clear and flowing narrative is incisive analysis on issues such as the contrast of Muir as mystic (although not a transcendentalist) yet man of action, his effectiveness in legislative action for conservation, and the influence of his father. Wilkins appropriately imbeds Muir's life within the historical context of the closing of the American frontier, expansion into the West, and the role of nature in the American mind. He explains supreme moments such as Muir's discovery of a rare orchid in Ontario and times with Emerson and Roosevelt. The seminal *Studies in the Sierra* is well reviewed, as is the split among conservationists of the utilitarians, advocating "wise use", and the preservationists like Muir, recognizing an intrinsic value to wilderness. Wilkins demonstrates how Muir's biocentric view and emphasis on the flow of ecological process makes him an important forerunner of Aldo Leopold. The continuing relevance of Muir is clear: his opposition to the damming of Hetchy Ketchy echoes through the Three Gorges, and as our century ends with as much rampant greed as the Gilded Age of a hundred years ago, it is piquant to hear him say of his friend the tycoon Harriman "He has not as much money as I have. I have all I want and he has not." For everyone interested in understanding why John Muir remains a major influence in conservation this book is highly recommended.

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NEW TITLES

Zoology

- Animal behavior: an evolutionary approach.** 1998. By J. Alcock. 6th edition. Sinauer, Sunderland, Maryland. xiv + 680 pp., illus. U. S. \$54.95.
- ***A birder's guide to the Bahama Islands (including Turks and Caicos).** 1998. By A. W. White. American Birding Association, Colorado Springs. x + 302 pp., illus. U.S. \$ 26.95.
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The Canadian Field-Naturalist is a medium for the publication of scientific papers by amateur and professional naturalists or field-biologists reporting observations and results of investigations in any field of natural history provided that they are original, significant, and relevant to Canada. All readers and other potential contributors are invited to submit for consideration their manuscripts meeting these criteria. The journal also publishes natural history news and comment items if judged by the Editor to be of interest to readers and subscribers, and book reviews. Please correspond with the Book Review Editor concerning suitability of manuscripts for this section. For further information consult: A Publication Policy for the Ottawa Field-Naturalists' Club, 1983. *The Canadian Field-Naturalist* 97(2): 231-234. Potential contributors who are neither members of *The Ottawa Field-Naturalists' Club* nor subscribers to *The Canadian Field-Naturalist* are encouraged to support the journal by becoming either members or subscribers.

Manuscripts

Please submit, **to the Editor**, in either English or French, **three** complete manuscripts **written in the journal style**. The research reported should be original. It is recommended that authors ask qualified persons to appraise the paper before it is submitted. Also authors are expected to have complied with all pertinent legislation regarding the study, disturbance, or collection of animals, plants or minerals. The place where voucher specimens have been deposited, and their catalogue numbers, should be given. Latitude and longitude should be included for all individual localities where collections or observations have been made.

Type the manuscript on standard-size paper, **double-space throughout**, leave generous margins to allow for copy marking, and **number each page**. For Articles and Notes provide a bibliographic strip, an abstract and a list of key words. Generally words should not be abbreviated but use SI symbols for units of measure. Underline only words meant to appear in italics. The names of authors of scientific names should be omitted except in taxonomic manuscripts or other papers involving nomenclatural problems. "Standard" common names (with initial letters capitalized) should be used at least once for all species of higher animals and plants; all should also be identified by scientific name.

The names of journals in the Literature Cited should be written out in full. Unpublished reports should not be cited here but placed in the text or in a separate Documents Cited section. Next list the captions for figures (numbered in arabic numerals and typed together on a separate page) and present the tables (each titled, numbered consecutively in arabic numerals, and placed on a separate page). Mark in the margin of the text the places for the figures and tables.

The **Council of Biology Editors Style Manual**, Fourth edition (1978) available from the American Institute of Biological Sciences, and **The Canadian Style: A Guide to Writing and Editing**, Department of the Secretary of State and Dundurn Press Ltd (1985) are recommended as general

guides to contributors but check recent issues (particularly in literature cited) for exceptions in journal format. Either "British" or "American" spellings are acceptable in English but should be consistent within one manuscript. **The Oxford English Dictionary, Webster's New International Dictionary** and **le Grand Larousse Encyclopédique** are the authorities for spelling.

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Photographs should have a glossy finish and show sharp contrasts. Photographic reproduction of line drawings, **no larger than a standard page**, are preferable to large originals. Prepare line drawings with India ink on good quality paper and letter (don't type) descriptive matter. Write author's name, title of paper, and figure number on the lower left corner or on the back of each illustration.

Reviewing Policy

Manuscripts submitted to *The Canadian Field-Naturalist* are normally sent for evaluation to an Associate Editor (who reviews it or asks another qualified person to do so), and at least one other reviewer, who is a specialist in the field, chosen by the Editor. Authors are encouraged to suggest names of suitable referees. Reviewers are asked to give a general appraisal of the manuscript followed by specific comments and constructive recommendations. Almost all manuscripts accepted for publication have undergone revision — sometimes extensive revision and reappraisal. **The Editor makes the final decision** on whether a manuscript is acceptable for publication, and in so doing aims to maintain the scientific quality, content, overall high standards and consistency of style, of the journal.

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Limited journal funds are available to help offset publication charges to authors with minimal financial resources. Requests for financial assistance should be made to the Business Manager when the manuscript is accepted.

Reprints

An order form for the purchase of reprints will accompany the galley proofs sent to the authors.

FRANCIS R. COOK, Editor
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